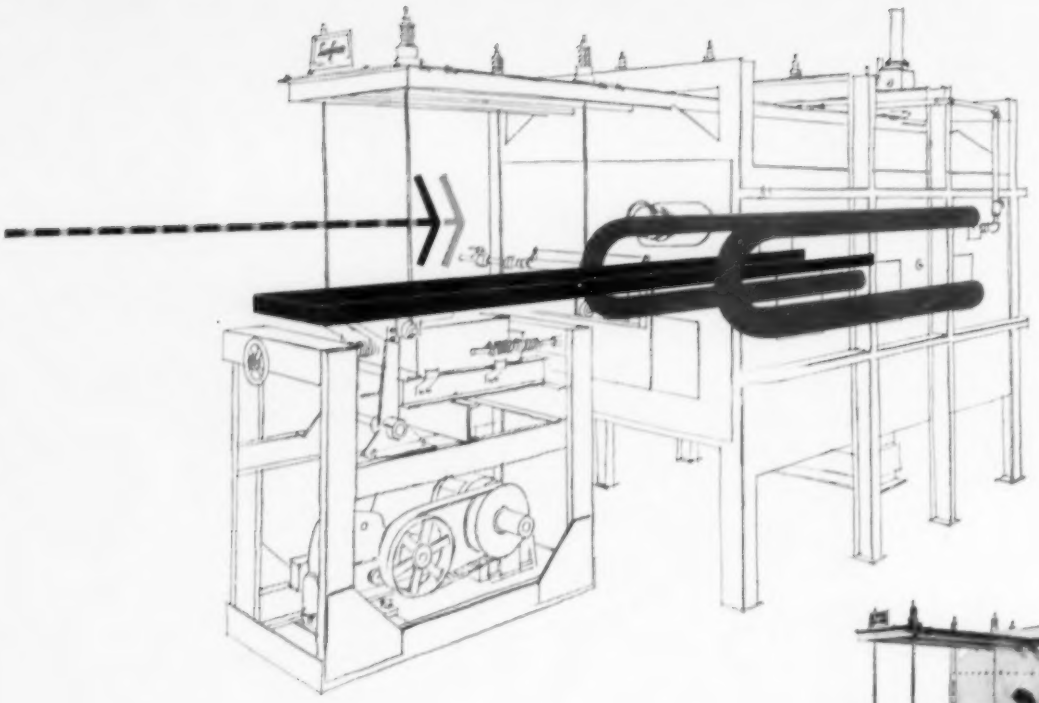
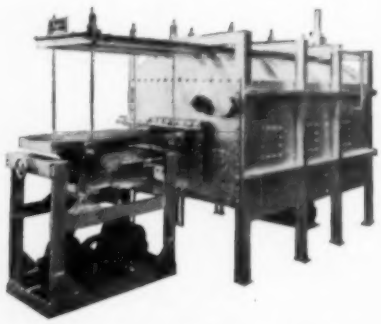
METAL Progress

JULY 1956





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The quantity and quality of small parts can be increased by controlled atmosphere heating and quenching in this new Surface® Snap Hearth Furnace. Production rates up to 300 lbs/hr are being attained in many plants.

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Metal Progress

Volume 70, No. 1

July 1956

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Cover by D. C. CRAWFORD—one of the prize-winners in *Metal Progress's* annual competition at the Cleveland Institute of Art.

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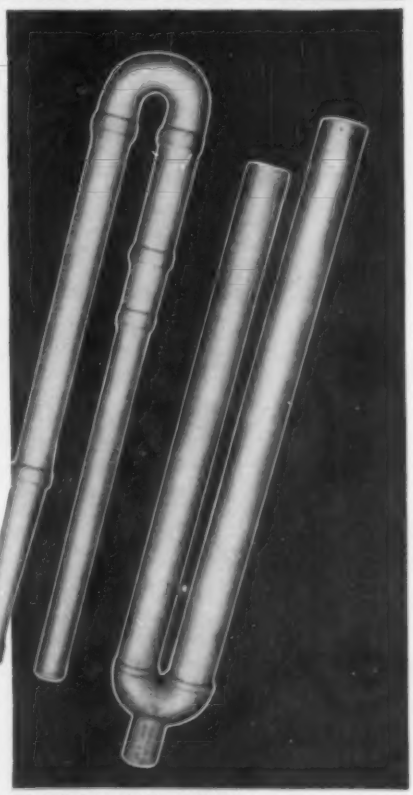

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there goes the profit...

use of impure ammonia for metal treating is a frequent cause of discoloration on finished parts

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As I was saying...

TEMPUS FUGIT – or something that sounds like it, as I grabbed my pen to rip off a few lines to my small but select coterie of understanding readers. These "flies in time" caught me up quick when I realized that just a year ago some 250 ASMers and their wives were seeing the sights of Europe and enjoying a hospitality such as we had never before experienced. The Metallurgical Societies Meeting in Europe was really the high-water mark of a flood of educational and memorable experiences.

I had one at least – the unusual experience of collapsing in a hotel lift, and riding via ambulance to the American Hospital in "Gay Paree" for a three-week sojourn. However, due to the careful and attentive care of "ze glorious French nurses" (they also had doctors at this hospital) I was soon convalescing on the Riviera where more epidermis is exposed to the actinic rays of the glorious Mediterranean sun than any place else on earth, except Bikini. Now, no matter where I go, everybody takes one look and exclaims, "Bill, what happened to you? You never looked so well." The only answer I can give is "I live right."

I had a very enjoyable experience the other day when I had dinner with General Alfred M. Gruenther, Supreme Commander of NATO. After dinner he told me about the proposed changes in the purposes of NATO and what we might expect in the future from that organization. He was very informative and I hope the 1642 other diners at the American Iron & Steel Institute annual dinner enjoyed it as much as I. I sure was proud of ASM's Bob Lynch, past chairman of the Georgia Chapter, and president of the Atlantic Steel Co., both when he addressed the meeting and when he sat at the speakers' table with the top brass – no, not brass – top steel men.

Here's another experience that gave me a real boost (not boot). The room telephone rang, and on my "Hello", President Schaefer spoke as follows: "Mr. Secretary, as chairman of a committee of the five immediate past presidents of the American Society for Metals, whose responsibility it is to nominate a secretary for the Society, I wish to notify you that you have been nominated for the 20th consecutive two-year term to be secretary of the ASM. Will you accept?" I answered, "Thank you, Mr. President, but first may I ask a few questions: Is the ASM a going organization?" "It sure is," said Pres. A.O.S., "and it's sure going places." Then I inquired, "How large is this Society?" Answer: "ASM has more than 26,000 members and 97 chapters." Just one more question, "Mr. President, what is its financial condition?" His reply swept away all doubts: "Why, we could pay your salary for the next forty years all in one lump and never miss it."

So what could I do? I said, "Mr. President, ordinarily I am a secretary of few words, but you've talked me into the job. I accept the nomination, and if I'm elected by the membership at the annual meeting in October I'll give my best."

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
AMERICAN SOCIETY FOR METALS

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Solventol service to metal cleaning goes beyond high quality cleaning compounds and highly efficient metal cleaning equipment.
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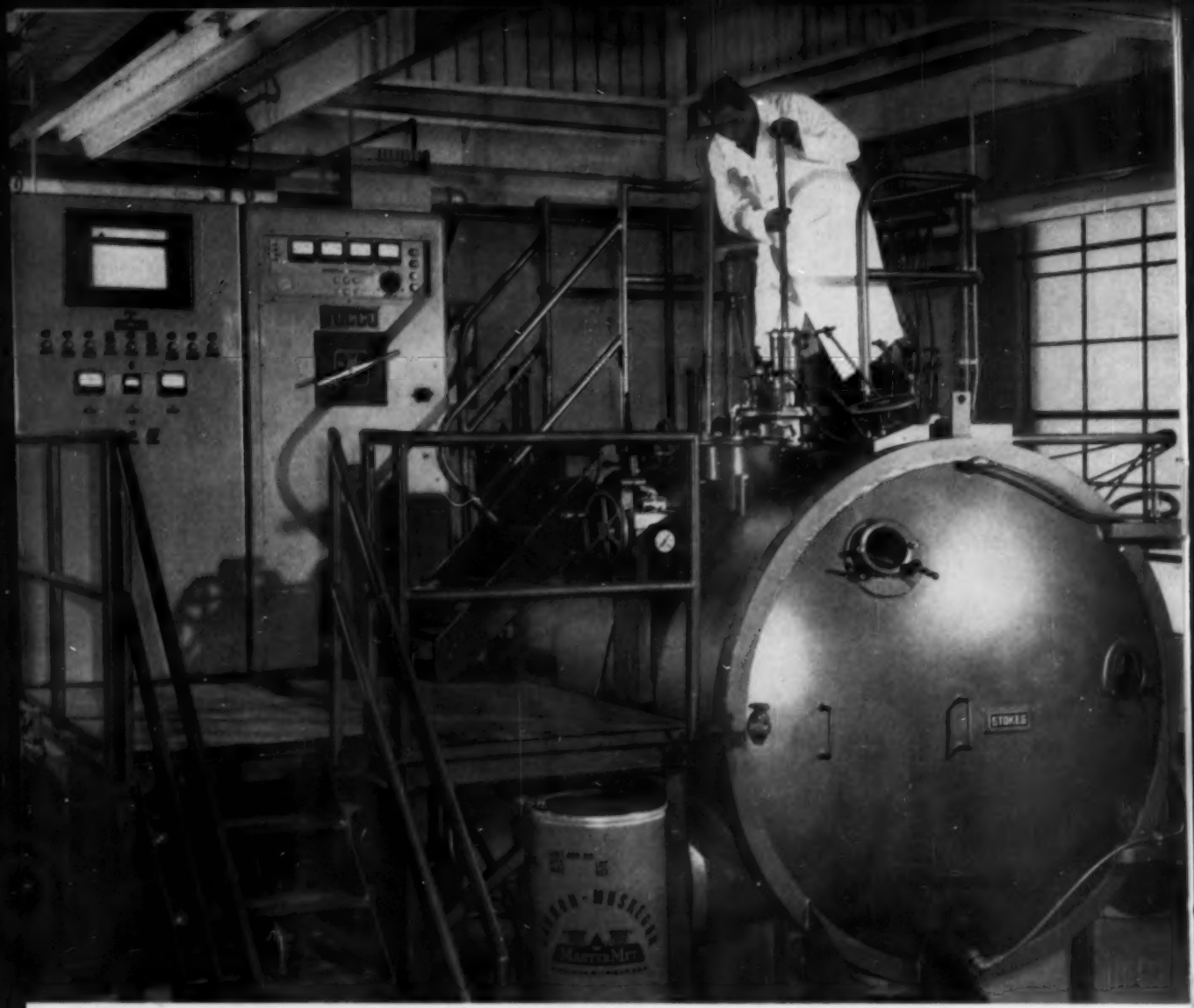
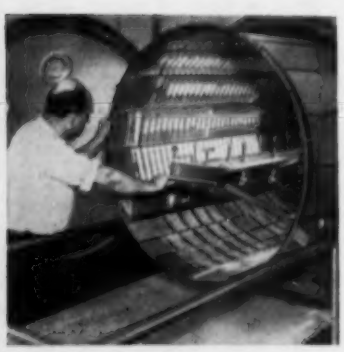


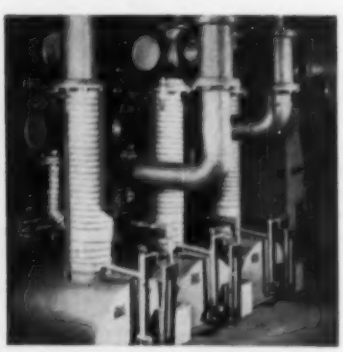
Due to Stokes vacuum lock design, operators can manipulate the melt during the heat without releasing vacuum. Furnace is used for production of special alloys at Cannon-Muskegon Corporation, Muskegon, Mich.

The metals industry is profiting from the use of other STOKES production equipment



Vacuum Metallizers. Stokes offers a complete line of vacuum metallizing equipment to plate metals for improved surface finish . . . also to provide conductive coatings on non-conductive materials.

Powder Metal Presses. Cost savings and the compacting of incompatible alloys have made powder metallurgy an accepted process. Stokes offers the most complete line of presses in the industry.



Vacuum Pumps. For rapid evacuation and holding high vacuums, Stokes offers mechanical pumps, and "Ring-Jet" oil vapor diffusion and booster pumps. New design affords 10 to 100% greater speeds.

"MasterMet" high temperature alloys vacuum melted in Stokes furnace

Another example of how Stokes vacuum furnaces aid industrial utilization of the new technology of vacuum metallurgy.

FOR the hot components of leading types of jet engines, Cannon-Muskegon produces a line of special vacuum melted alloys. Engineered primarily for high temperature service, these alloys are supplied as ingots and billets for investment casting.

A Stokes Vacuum Furnace provides performance to the exacting specifications required for this work. Its design is the result of close cooperation between Cannon-Muskegon and Stokes engineers. The furnace has a capacity of 500-pounds per heat.

In the words of George W. Cannon, Jr., company president, "The equipment has performed in accordance with our specifications . . . a leak rate of 8 microns per hour . . . and permits pouring of vacuum alloys at pressures less than 10 microns."

If you are planning to explore the interesting potential of modern vacuum metallurgy, plan, too, to take advantage of the undisputed leadership in equipment and experience which Stokes can apply to your problem. Prime supplier of vacuum furnaces for production use, Stokes incorporates the features you need for simplified operation and dependable service. With the Stokes vacuum lock, you can make multiple melts and manipulate the melt without breaking the vacuum. High capacity pumping systems, combining new Stokes Ring-Jet Booster Pumps and rugged Microvac roughing pumps provide fast evacuation and dependable holding of desired vacuum.

A Stokes engineer will be glad to consult on your specific application, help you select the most suitable of the many basic Stokes designs for your work, and engineer modifications to your special requirements. For technical data, write for Stokes Catalog No. 790, "High Vacuum Furnaces."

F. J. STOKES MACHINE COMPANY, *Vacuum Furnace Division*, 5506 Tabor Road, Philadelphia 20, Pa.

Reference Data:

Microvac Pumps—Catalog 750
Diffusion and Booster Pumps
Specification and performance data
Story of the Ring-Jet Pump
How to Care for Your Vacuum Pump—
Booklet 755
Vacuum Furnaces—Catalog 790
Vacuum Metallizing—Catalog 780
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Powder Metal Presses—Catalog 810

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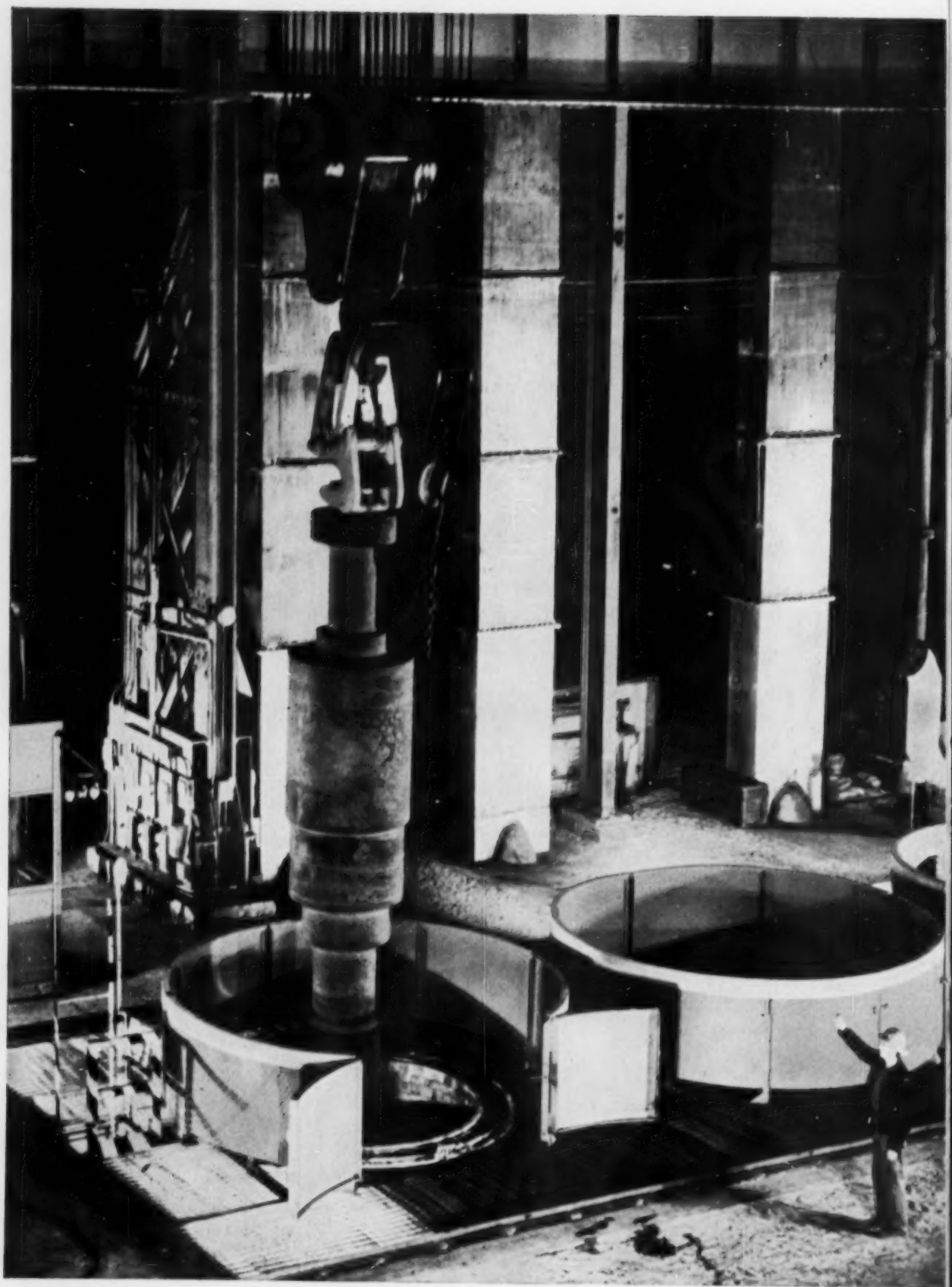


Giants, too, heated without distortion

Westinghouse pressurized furnaces keep 30-ft forgings "straight as an arrow" at U. S. Steel

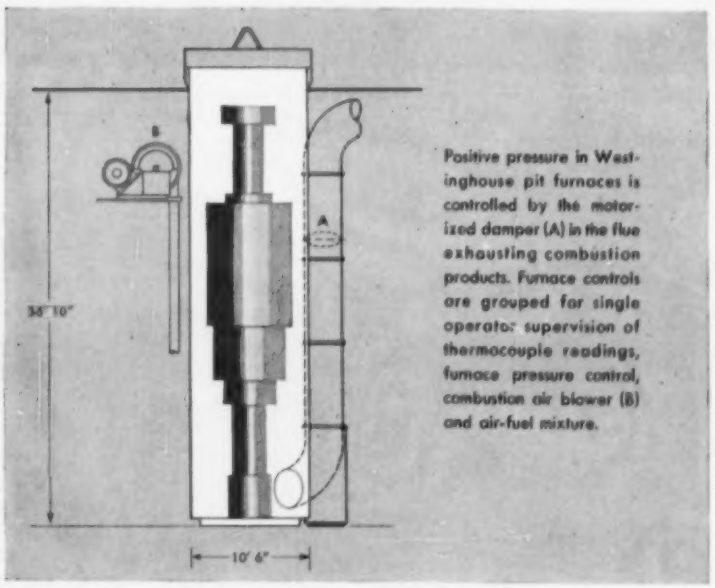
Three large, Westinghouse pit-type furnaces at U. S. Steel's Homestead Works are built to pamper giant forgings. This turbine rotor, for example, lifts out straight and true at 1830°F. During eight hours of soaking heat the temperature along its 30-foot length never varied as much as 10°F. Distortion was never a problem because of Westinghouse temperature control and positive pressure furnace design.

In this design even heating is assured through back pressure control of combustion gases. With positive pressure in the furnace any air leakage is always outward. Thus localized chilling of the work is prevented. The furnace is tangentially fired by means of spirally located burners and is equipped with 3 zones of automatic temperature control. Since the products of combustion are sucked out from the bottom of the furnace, heat currents make two passes the full length of the work...once upward, once downward.

In Westinghouse experience with gas, electric, or induction heating equipment, we have undoubtedly solved a problem like yours. You can be sure of our broad experience by calling your local Westinghouse industrial heating engineer today or write Westinghouse Electric Corporation, Industrial Heating Division, Meadville, Pa. J-10451

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING **TODAY!***



Positive pressure in Westinghouse pit furnaces is controlled by the motorized damper (A) in the flue exhausting combustion products. Furnace controls are grouped for single operator supervision of thermocouple readings, furnace pressure control, combustion air blower (B) and air-fuel mixture.

W. E. Collar reports . . .*

Facts to lick your distortion problem

Unusual facilities and experience at Westinghouse have enabled us to jump years of trial-and-error methods in engineering furnaces and induction heating equipment to prevent distortion. We're constantly after better ways to gain temperature uniformity in metal processing equipment. This is necessary not only to prevent distortion but also to obtain desired metallurgical properties.

On special problems, our equipment design engineers have the advantage of facts gained through Westinghouse metallurgical research activities. Production testing of equipment design and engineering is carried out by our Materials Manufacturing Division at Blairsville, Penna. These activities back up our long experience in gaining accurate heat distribution for positive temperature uniformity.

The results can be seen in a Westinghouse furnace used for the air tempering of rotors for atomic equipment. Accurate heat control designed into this electrically heated furnace meets demanding requirements for distortion-free work.

Another case in point is the work on distortion problems under way in our induction heating laboratory. Here equipment is being developed for distortionless hardening of automotive axles.

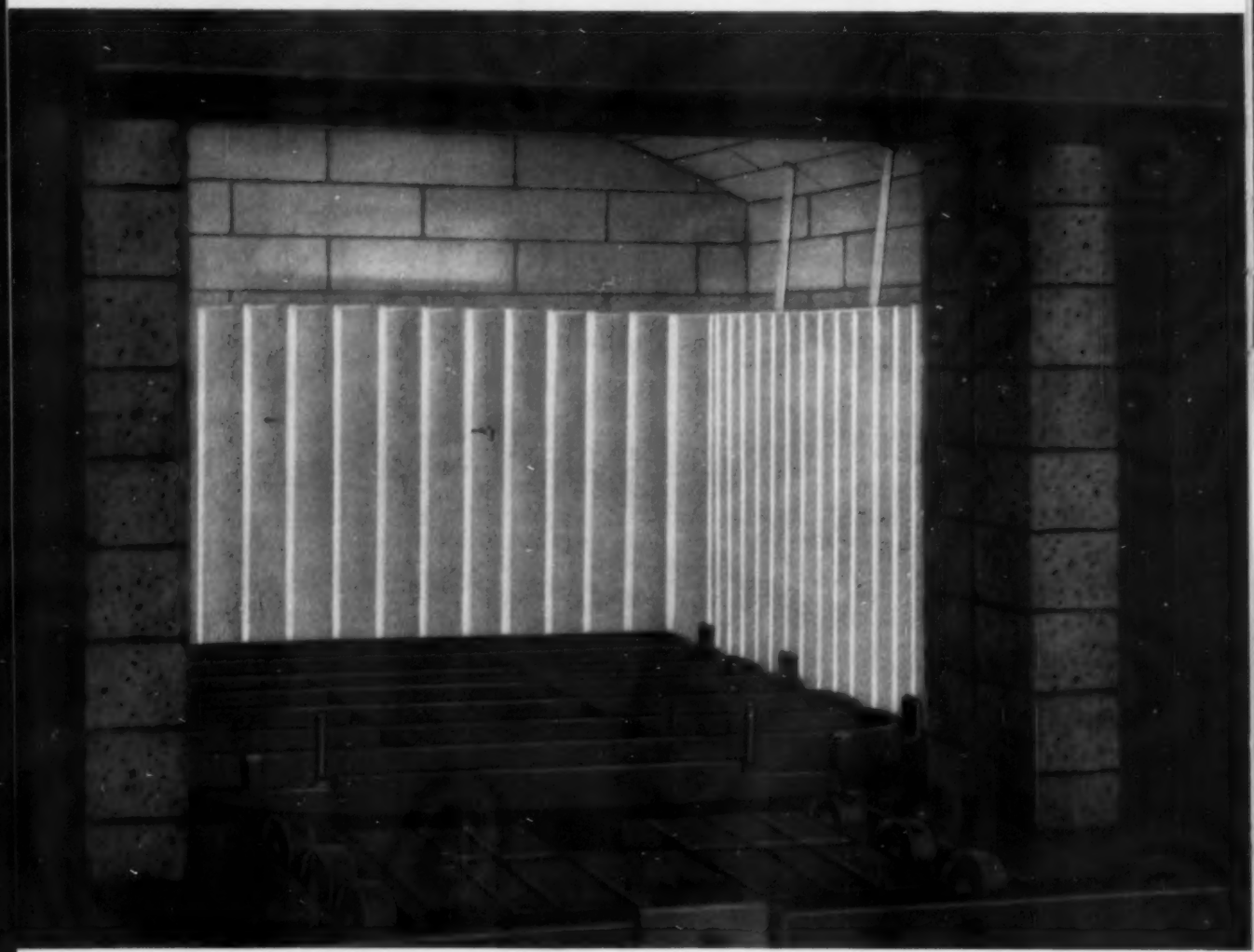
The teamwork that solved these application problems is your assurance of getting the latest in engineering development and the finest equipment for all your metal processing needs.

**Manager, Industrial Heating Dept.*

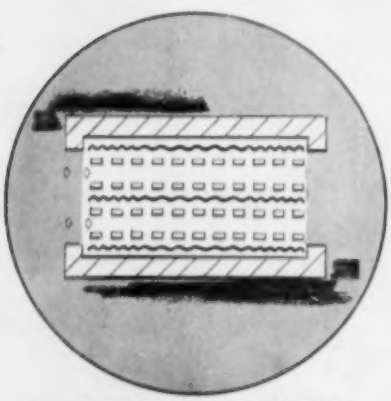
The Westinghouse Heat-Treating Family

GAS • ELECTRIC • INDUCTION

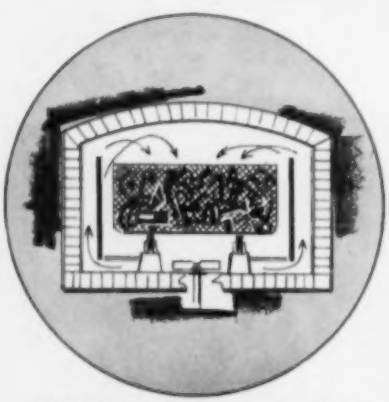
BRAND NEW – MODERN ELECTRIC ELEMENT



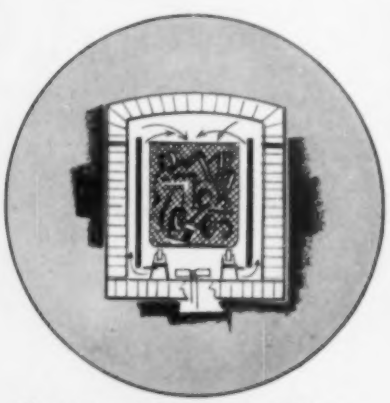
This shows graphically how the new Lindberg CORRTHERM electric heating element actually fills the furnace with walls of glowing heat. Note also that CORRTHERM is conveniently hung from simple brackets requiring no complicated connections or construction. This element operates at extremely low voltage, eliminating shock or short hazards.



In continuous type furnaces CORRTHERM elements hang between lines of work as well as on side walls. Note how closer corrugations (at each end of element) compensate for incoming cold work and door losses.



CORRTHERM elements act as natural baffles to direct forced convection streams through the charge. The use of electric furnaces for carburizing and carbonitriding now becomes completely practical.



No retort needed in pit-type carburizing furnace with CORRTHERM elements. Again see how elements serve as baffles to direct forced convection stream through charge.

FOR LINDBERG FURNACES

Never before has there been an electric heating element like this CORRTHERM by Lindberg. Its revolutionary advantages now make the use of electricity as the source of heat, practical, efficient and economical for all heat treating processes.

Ideal for use in any electric heat treating furnace, CORRTHERM elements have particular advantages for carburizing and carbonitriding. This new element completely eliminates problems formerly created by the use of electricity in these types of furnaces. These exclusive advantages of CORRTHERM explain how and why:

LOW VOLTAGE: Operates at extremely low voltage. No leakage through carbon saturation. Around Lindberg we talk about it as the electric element "without any electricity . . . to speak of!"

ATMOSPHERE CIRCULATION: Elements act as baffles to direct circulation of convection streams.

SAFETY: Extremely low voltage also eliminates shock or short hazards.

DURABILITY: Watts density at all-time low. Element practically indestructible. Work load or operator's charging tool can't hurt it.

EASILY INSTALLED: Element is not enclosed, just hangs in furnace. No complicated mountings required.

If electricity is the preferable source of heat for your metal treating processes find out how advantageously CORRTHERM elements can be applied to your requirements. Just get in touch with your nearest Lindberg Field Representative. (Consult your classified phone book.)

LINDBERG

LINDBERG ENGINEERING COMPANY

2448 West Hubbard Street, Chicago 12, Illinois

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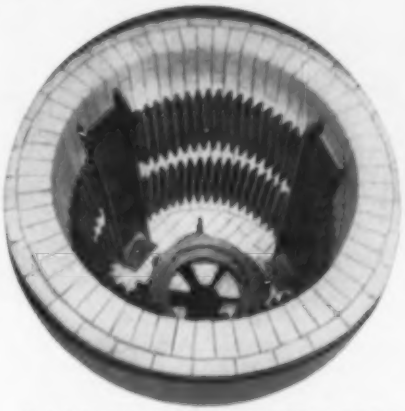
Associate Companies: Lindberg Industrial Corporation, Chicago • EPCO-Lindberg, Ltd., Montreal, Canada
Lindberg Italiana, Milan, Italy • The Electric Furnace Company, Ltd., Weybridge, Surrey, England
Etablissements Jean Aubé, Paris, France • Lindberg Industrie Ofenbau, Gross Auheim, Germany

CORRTHERM elements are large sheets of corrugated nickel chromium. They were developed in Lindberg laboratories by Lindberg metallurgists and engineers.

This shows installation of CORRTHERM elements in one of two large rotary furnaces currently being erected in the field by Lindberg's associate company, Lindberg Industrial Corporation.



An installation of CORRTHERM elements in a carburizing pit-type furnace. Simplicity of mounting makes replacement easy and economical.

Safety! Extremely low voltage makes CORRTHERM elements completely safe. Let operator or work load bang it if they will. Neither element nor operator will be hurt.

CORRTHERM

by LINDBERG

WHICH PRODUCTION PATTERN IS YOURS?

JOB LOTS—VARIETY OF SMALL PARTS

JOB LOTS—VARIETY OF LARGE PARTS

HIGH PRODUCTION—SAME SMALL PARTS

HIGH PRODUCTION—SAME LARGER PARTS

NOW . . . 4 NEW G-E INDUCTION HEATERS MATCH

You get maximum induction heater performance at minimum investment cost when you choose one of General Electric's new electronic induction heater models. Each model is tailored to one of the basic production patterns illustrated above. This lets you buy only the induction heating features you need for your particular production pattern.

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FOR HEATING SMALL AREAS the built-in output transformer is recommended. This feature enables you to couple power at maximum efficiency into a wide variety of low-impedance inductor coils.

FOR HEATING LARGER AREAS the tapped tank coil is recommended. The tap-adjustment feature lets you couple the heater power into a wide variety of high-impedance inductor coils.

FOR JOB-LOT PRODUCTION OF A WIDE VARIETY OF PARTS, variable power adjustment is recommended. Grid control of thyratron tubes permits manual adjustment of power under load from 0 to 100 per cent.

FOR HIGH-VOLUME PRODUCTION, IN WHICH YOU DO NOT HAVE RAPID CYCLING, the variable power adjustment feature is not needed. In these applications, the heater is adjusted initially to heat a specific part. No further adjustment is necessary until you change to a different part.

Features in any of the four ratings can be combined in the following fashion:

Model	Thyratron	Output Transformer	Tapped Tank Coil
4HM L1	x	x	
4HM L2		x	
4HM L3	x		x
4HM L4			x

Your nearby G-E Heating Specialist will help you choose the model best suited to your production pattern. You'll be paying only for those induction heater features you will use in your operation.

For specific bulletin information about these new induction heaters send in the coupon at the right.

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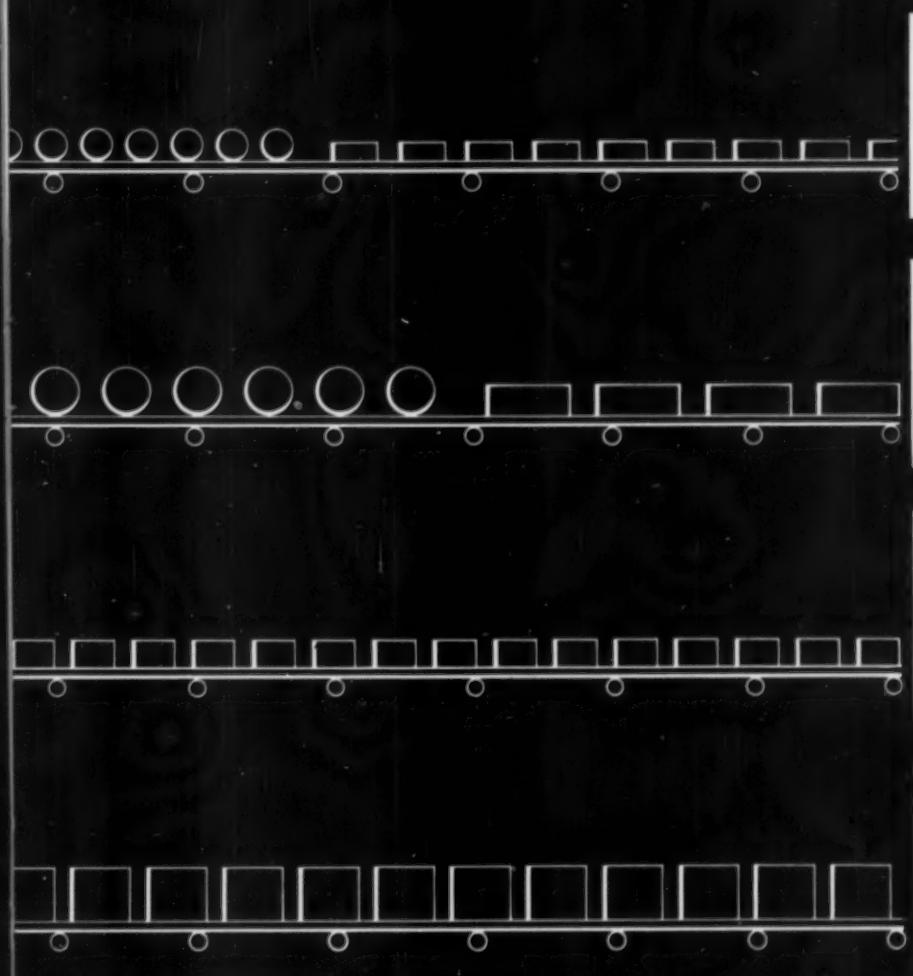

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High KVA Oscillator	✓
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Whatever your furnace needs for control—

There's good reason why more heat-treating furnaces everywhere are controlled by Brown instruments. First, of course, is performance . . . sensitive, precise control that meets the most exacting requirements of modern heat-treating techniques. And equally important is versatility. In this varied line of instrumentation you'll find just about everything a furnace could possibly need in the way of control.

Choose *ElectroniK* Strip Chart Controllers for detailed, long-term records . . . and a selection of control forms including electric systems of the contact, position-proportioning (*Electr-O-Line*) and time-proportioning (*Electr-O-Pulse*) types; and pneumatic control from two-position to full proportional-plus-reset-plus-rate action.

Choose *ElectroniK* Circular Chart Controllers for ease of scale reading . . . convenient daily charts; in a full range of electric and pneumatic control forms.

Note: the basic components of all *ElectroniK* models are interchangeable . . . to simplify and speed up service.

Choose *ElectroniK* Circular Scale Controllers where you want readability and control check at extreme distance . . . without need for a record. Supplied with all contact and proportional types of electric control.

Note: all *ElectroniK* models are available in both Standard and Precision Series.

Choose *Pyr-O-Vane* Controllers where you don't need a record but do need precise vane type snap action electric control by a millivoltmeter instrument... also available with pulse-type time proportioning action, in both vertical and horizontal models.

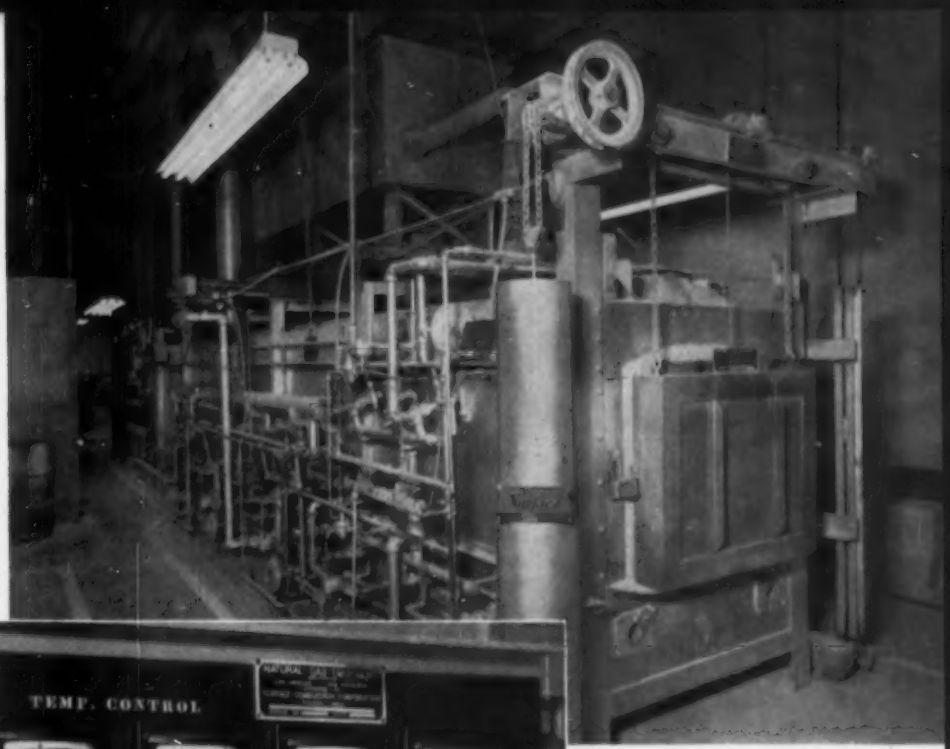
Choose the *Protect-O-Vane* Safety Cut-Off for simple, dependable excess temperature protection ... can be used with any temperature control to prevent furnace shut downs and loss of production.

• • •

And ... for all your pyrometer supplies, investigate the convenience and economy advantages of the HSM Plan.

Investment casting molds preheated precisely ... *in "Surface"*

Bulletin B43-1 is a handy reference . . . lists specifications and prices for all ***ElectroniK*** *control instruments,* ***Pyr-O-Vane*** *millivoltmeter pyrometers, Brown thermometers, and associated safety equipment, valves and accessories. Write for your copy today.*



Pyr-O-Vane Controllers regulate zone temperatures in roller-type furnace for preheating investment molds.

furnace with Pyr-O-Vane control

ARWOOD PRECISION CASTING COMPANY, of Los Angeles, makes a specialty of close-tolerance investment casting of scores of intricately shaped parts. Preheating of the molds, during which time wax is burned out, is a phase of processing essential to precision in the finished product.

To get the needed combination of accuracy and production capacity the company performs the preheat operation in a big Surface Combustion furnace, supplied by Natural Gas Equipment, Inc. of Pasadena. The pusher-type gas furnace is 30 feet long, and has four progressive temperature zones. A *Pyr-O-Vane* millivoltmeter instrument controls each zone independently, at temperatures from 200 to 1600 F. Overall precision of control guarantees that molds are held to the close tolerances required by the investment process. And these tolerances are held at production rates of a tray of molds *every 20 minutes*.

Whatever your heat-using application, you can rely on the proved accuracy and dependability of Brown instruments to give you top performance at economical cost. A complete line of measuring and controlling instrumentation is available. For a discussion of your specific requirements, call your local Honeywell sales engineer . . . as near to you as your phone. MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

● **REFERENCE DATA: Write for Catalog B43-1, "Furnace and Oven Controls."**

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

SPECIAL REPORTS ON FINISHING NON-FERROUS METALS

NUMBER I—Decorative, Corrosion-Resistant Finishing with Iridite

Chromate conversion coatings are well known and accepted throughout industry as an economical means of providing corrosion protection, a decorative finish or a good paint base for non-ferrous metals. However, continued developments are so rapid and widespread that many manufacturers may not be completely aware of the breadth of application of this type of finish. Hence, this digest of current information; to bring you up to date on the many ways in which you can combine salable appearance with durability in one finish at a competitive price advantage. Report II on paint base, corrosion-resistant finishes and Report III on chemically polished, corrosion-resistant finishes are available on request.

First, as a basis for this discussion, a "decorative" finish is considered as any chromate film that is used as a final finish in itself. It may be truly decorative in that its sole purpose is to enhance the beauty of the product. For example, a bright chrome-like finish or a pleasing bronze appearance are among the many effects that can be obtained. It may be functionally decorative in that it reduces reflectivity for camouflage purposes or provides a means of color-coding parts. But, in all cases, the Iridite films protect the metal against corrosive attack.

Iridite finishes are now available for all commercial forms of the more commonly used non-ferrous metals, including zinc, cadmium, aluminum, magnesium, silver, copper, brass and bronze. These films can produce a wide variety of pleasing appearances. The basic colors of the Iridite coatings are grouped below by metals.

ZINC and CADMIUM: Metallic bright, light iridescent, iridescent yellow, bronze, olive drab.

COPPER, BRASS, BRONZE: Metallic bright, yellow.

ALUMINUM ALLOYS: Clear, iridescent yellow, brown.

MAGNESIUM ALLOYS: Metallic bright, iridescent yellow-red, brown.

SILVER: Metallic bright.

In addition, many films can be modified by bleaching or by dyeing. Among the dye colors available are various shades of red, yellow, green, blue or black.

Depending upon the metal and the Iridite used, corrosion resistance of clear and bright films ranges from mild passivity to as high as 500 hours in salt-spray; on heavier dark films, salt-spray resistance ranges from approximately 100 to 1000 hours.

It is this combination of decorative and corrosion resistant properties that accounts for the widening use of Iridite finishes. For example, Iridites #4-73 and #4-75 (Cast-Zinc-Brite) make possible for the first time, a combination of lustrous chemical polishing of the as-cast surface of zinc die castings and good resistance to corrosion. Further, in many cases, sizeable savings in the cost of buffing and electroplating are realized.

WHAT IS IRIDITE®?

Briefly, Iridite is the tradename for a specialized line of chromate conversion finishes. They are generally applied by dip, some by brush or spray, at or near room temperature, with automatic equipment or manual finishing facilities. During application, a chemical reaction occurs that produces a thin (.00002" max.) gel-like, complex chromate film of a non-porous nature on the surface of the metal. This film is an integral part of the metal itself, thus cannot flake, chip or peel. No special equipment, exhaust systems or specially trained personnel are required.

On many steel parts, a simple system of zinc or cadmium plate and bright Iridite is used instead of more costly electroplated finishes to provide a bright, decorative and protective finish with tremendous savings in material, equipment and labor.

In finishing aluminum, where corrosion resistance or paint adherence is the prime consideration, the aircraft industry has all but abandoned the anodizing process in favor of recently developed chromate conversion coatings, among them Iridite #14 and #14-2 (Al-Coat). These formulations and their method of application can be varied to retain the original metallic appearance while providing acceptable corrosion resistance, or to produce a fully colored brown finish that offers exceptional corrosion protection. Again, time and manpower savings are astounding—one company saved at least $15,000 a year on maintenance of racks alone and another $40,000 on materials and labor in only nine months. In addition, of course, hundreds of thousands of dollars are saved by eliminating the need for expenditures for generators, heating equipment and racks.

Iridites are widely approved under both Armed Services and industrial specifications because of performance, low cost and savings of materials and equipment.

In planning or designing, you should consider the many other characteristics of Iridite finishes which may enter into the specific problem. In addition to having decorative and protective functions, these chromate coatings form an excellent base for organic finishes and bonding compounds. They have low electrical resistance. Some can be soldered and welded. The Iridite film itself does not affect the dimensional stability of close tolerance parts.

You can see then, that with the many factors to be considered, selection of the Iridite best suited to your product requires the services of a specialist. That's why Allied maintains a staff of competent Field Engineers—to help you select the Iridite to make your installation most efficient in improving the quality of your product. You'll find your Allied Field Engineer listed under "Plating Supplies" in your classified telephone book. Or, write direct and tell us your problem. Complete literature and data, as well as sample part processing, is available. Allied Research Products, Inc., 4004-06 E. Monument Street, Baltimore 5, Maryland.

2 GREAT NEW SILVER BRAZING FLUXES...

The broad variations in joint design, metals and methods encountered in low temperature silver brazing make it impossible to manufacture a single flux to act with maximum efficiency on all jobs. A large proportion of routine brazing work can be accomplished efficiently with a general purpose flux but in an increasing number of instances, manufacturers are finding that more rapid, consistent production, greater economy and fewer rejects are a matter of record by selecting correctly from the APW line.

Four standard APW formulae (APW1100, APW-1200, Deoxo and Black Flux) are available to simplify selective fluxing for you, to insure complete efficient protection in any classification of silver brazing. They enable the technician to key the selection of flux to the precise requirements of the job in production.

A "Complete Guide To Selective Fluxing" will be sent you upon request. It contains complete, factual data that you should know. If you wish, an expert Silvaloy Technician will be glad to consult with you, at your convenience. Call the Silvaloy Distributor in your area or write us directly. ★ ★ ★ ★ ★ ★

IF EXTRA COPIES ARE DESIRED FOR BRAZING PERSONNEL PLEASE SEND REQUEST ON COMPANY LETTERHEAD

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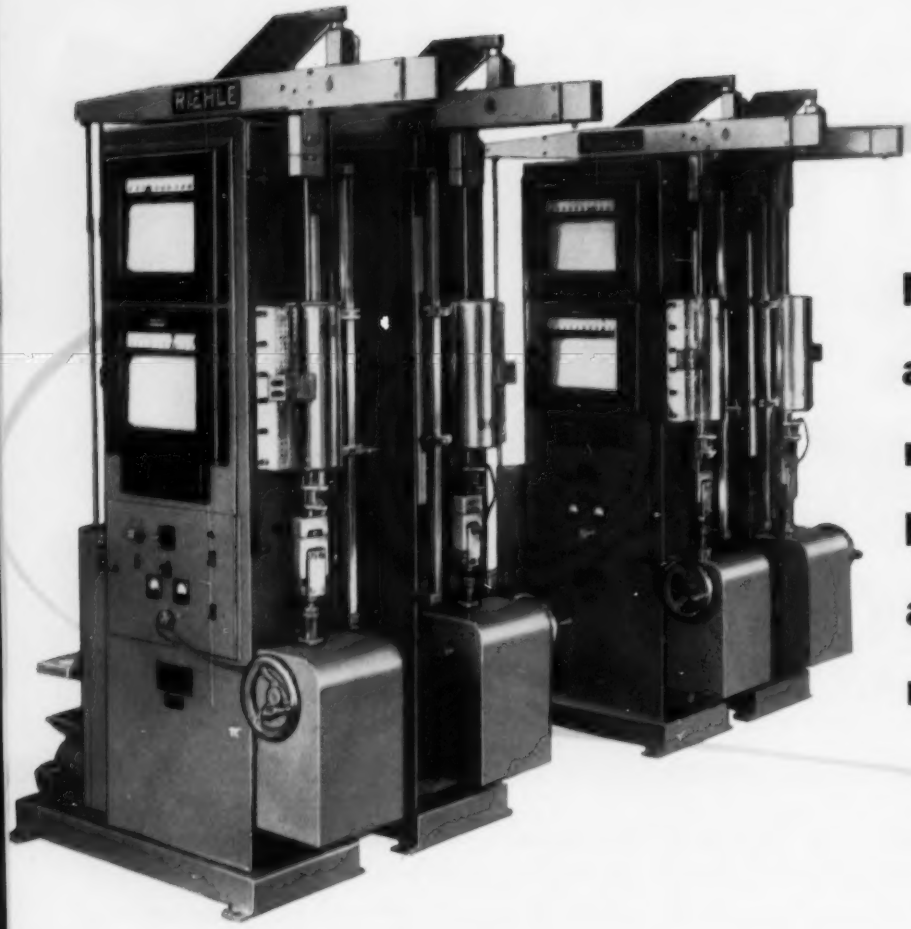

NOW complete, authoritative records of hi-temp creep and stress-rupture tests

No longer need creep and stress rupture data be incomplete . . . inadequate. The Riehle testing machine can be furnished with high-temperature creep extensometer and Riehle-built autographic creep-time recorder. Accordingly, each test furnishes complete, authoritative information.

The Riehle Creep and Stress-Rupture Testing Machine is usually furnished with temperature controller, furnace, local wiring and other necessary components — fully ready to operate. Its design can accommodate a wide range of accessories and instrumentation to insure maximum versatility. This machine is the product of the very best in modern engineering technology and fabricating practice.

NEW 8-page bulletin describes "package" testing machine... instrumentation ... accessories

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ATTENTION MR.

APPLICATION and EQUIPMENT new products

Controlled Atmosphere Furnace

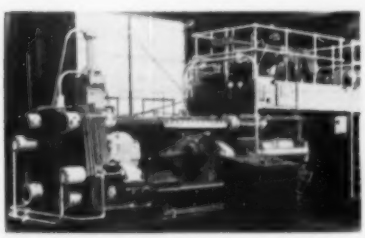
A new and larger model of fully automatic, controlled atmosphere tool room furnace has been announced by Cooley Electric Manufacturing Corp. It is fully automatic as to furnace controls, generator and temperature

controls, as well as to the gas curtain operation. The atmosphere system consists of a cracking unit to which is fed, by means of a variable speed pump, a mixture of alcohol and water proportioned to the type of treatment desired. This mixture is cracked into gas of a controlled analysis to maintain the correct carbon potential for equilibrium with the steel being treated.

For further information circle No. 1 on literature request card, p. 48-B.

Extrusion Press

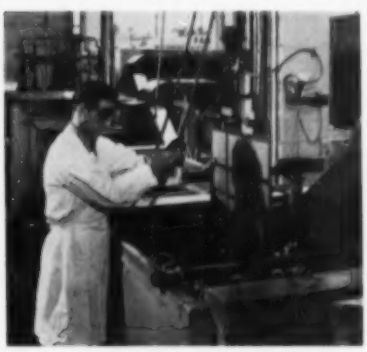
Sutton Engineering Co. has announced a new 1250 to 1500 ton extrusion press. The new unit features an exclusive electro-hydraulic control system which makes possible high-speed extrusion of 24-in. long aluminum billets of 5 or 6 in. in diameter at a rate of over 50 per hour. The new Sutton control provides for the operator's immediate selection of three different operating cycles: manual, automatic control for dies requiring butt shearing and automatic control for bridge-type dies.



For further information circle No. 2 on literature request card, p. 48-B.

Chemical Milling

A complete pilot line for the chemical milling of steel and titanium has been announced by Turco Products, Inc. It consists of a series of especially designed processing tanks, equipped with sensitive temperature controls. A scrubber system has also been designed to treat effluent gases from the tanks. Hundreds of intricate aluminum parts have been precision contoured by the process. It has been found that chemical milling

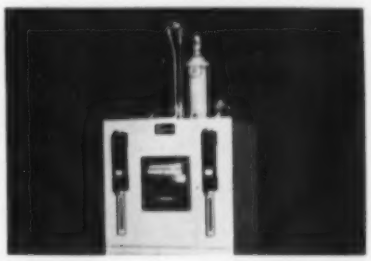


is suited for the replacement of metal-to-metal bonding and spot welding of integral parts, where fastening failures have often been reported in the past. The Chem-Mill process of metal forming does not appreciably impair the physical or mechanical properties of the metal, and a minimum of warpage is experienced in processing forgings. The number of parts that can be milled simultaneously is limited only by the number and capacities of tanks employed.

For further information circle No. 3 on literature request card, p. 48-B.

Laboratory-Size Gas Generator

A new laboratory-size endothermic gas generator has been announced by Ipsen Industries, Inc. This electrically

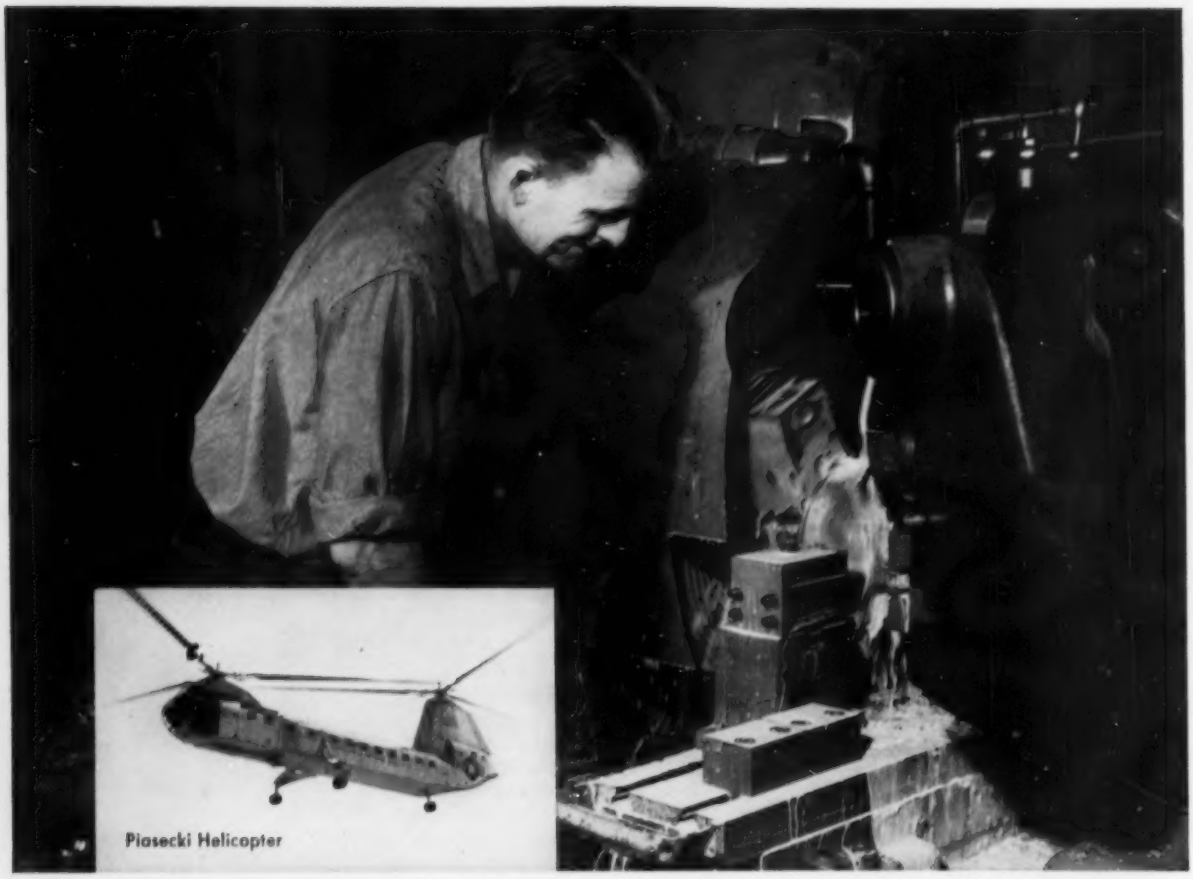


heated generator is intended for the small scale heat treatments usually required in the laboratory or tool room heat treat department. Rated output is approximately 150 c.f.h. of prepared atmosphere gas, but this output can be increased by approximately 50% when required.

For further information circle No. 4 on literature request card, p. 48-B.

Sheet Steel Separators

E. V. Nielsen has announced redesigned Basco sheet steel separators which are protected from the demagnetizing influence of metal and metal dust particles by a non-magnetic case. Other features are a reinforced aluminum frame, with a molded handle for ease and convenience in moving the units to different jobs. The base of the unit has been designed so that it may be clamped to the work surface



Sun's Heavy Duty Emulsifying Cutting Oil excels on high-alloy aircraft steels

S.E.C.O. Heavy Duty handles all machining jobs requiring an emulsifying cutting oil. Piasecki Helicopter's large job shop at Morton, Pa., found this out three years ago when S.E.C.O. HD* replaced two expensive heavy-duty soluble oils in machining fan hubs.

Extremely versatile and moderately priced, S.E.C.O. HD has been doing an exceptional job in cutting a variety of high-alloy aircraft steels for Piasecki.

For more information about S.E.C.O. HD, see your Sun representative. Or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-7.

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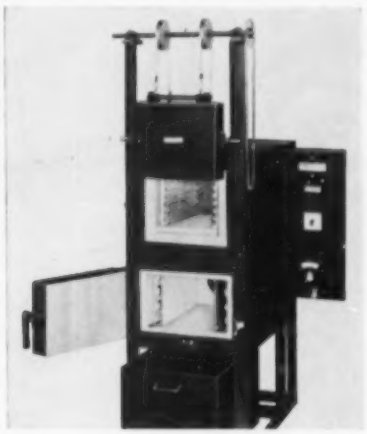
or held securely by bolts through the holes in the base. Stainless steel wear strips, bolts and cap nuts are used throughout to avoid shunting of the magnetic field. The separators are permanent magnet units that induce a magnetic field in stacked sheet steel when the unit is placed at the front or side of the stack. The magnetic field created causes the steel sheets to repel each other, with the top sheets fanning out with air space between them. As the top sheets are removed, the sheets below automatically move up, with this action repeating to the bottom of the stack.

For further information circle No. 5 on literature request card, p. 48-B.

Electric Furnace

Lucifer Furnaces has announced a new combination hardening and drawing furnace. Two furnaces, one above the other, have independent controls



and occupy the floor space of one unit. The hardening furnace is available to 2000 or 2300° F. and the drawing furnace to 800° F. Quench tank is included with all but the largest standard models.

For further information circle No. 6 on literature request card, p. 48-B.

Testing Machine

An automatic testing machine for maintaining a fixed extension or strain when testing at elevated temperatures has been announced by Tinius Olsen Testing Machine Co. This automatic relaxation tester operates on a principle directly opposite to that of the more familiar creep tester. The specimen is inserted in a circular testing furnace mounted between the crossheads. This electric furnace can be used for testing at any temperature up to 1800 to 2000° F. with temperatures controlled by a separate unit adjacent to the machine. To perform the test, a pre-

determined extension (in inches per inch) is selected, and the machine started at the desired loading speed. Load is applied to the specimen until the fixed extension is attained. As the specimen tends to strain further under the influence of increasing temperature and load, the amount of load is automatically reduced to maintain the fixed extension. All variations of the test are recorded by the XY electronic recorder mounted in the face of the machine.

For further information circle No. 7 on literature request card, p. 48-B.

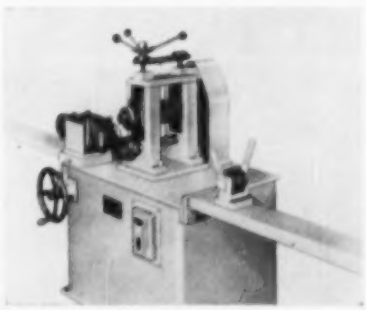
X-Ray Film

A new industrial X-ray film which retains fine sensitivity with greatly reduced exposure has been announced by the Eastman Kodak Co. The new Type AA has been developed to provide new versatility in working with all types of X-ray machines and gamma ray sources. Film speed ranges from approximately 1.3 to more than 2 times that of the widely used Type A film.

For further information circle No. 8 on literature request card, p. 48-B.

Bar Stock Marker

To meet the need of the medium and small machine shops, Marking Machine Co. has announced a machine for pre-marking steel, brass or aluminum bar stock before loading in automatic screw machines. The bar stock



marker permanently marks one side or opposite sides of the stock simultaneously. The only adjustment required is made by turning the handle on top of the unit to raise or lower

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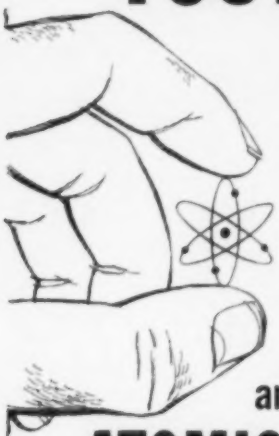

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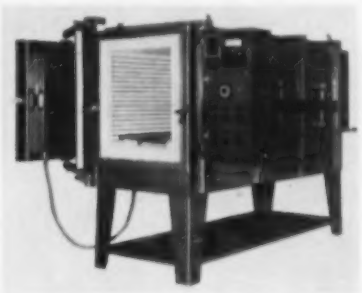
FIRST IN ATOMIC POWER

the rolls for various bar sizes. It will mark any stock from ⅝ to 3 in., round or hexagonal.

For further information circle No. 9 on literature request card, p. 48-B.

Heat Treating Furnace

The L & L Manufacturing Co. has announced a new furnace designed for many critical temperature heat treating operations where furnace gradients must be controlled closely. The interior dimensions of this furnace are 24 in. wide by 24 in. from hearth to roof and 72 in. long. There are six zones in the furnace and the input to each is controlled by an input controller which may be set from 7% to 100% of input in increments of 1%, giving precise control over the rate of heating in that zone.



For further information circle No. 10 on literature request card, p. 48-B.

Forgings

This crankshaft was forged at Erie Forge & Steel Corp. from a 72 in. diameter medium carbon steel ingot weighing 210,000 lb. The weight of the rough forging was 108,460 lb., slab size 34⅝ in. by 23 in. by 45 ft. It was machined to 46,000 lb. finished weight.

For further information circle No. 11 on literature request card, p. 48-B.

Barrel Deburring

An alkaline material designed for the barrel deburring of small parts has been announced by Oakite Products, Inc. FM 183 combines a fine, fast-cutting abrasive with surface active agents designed to keep media

MARTINDALE

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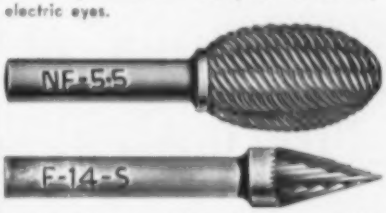
Made of high-speed steel. Produced in our own factory where uniform hardness is assured by heat-treating in electric furnaces on which the temperature is closely controlled by electric eyes.



Over 200 sizes and shapes (total over 75,000 pieces) are carried in stock for immediate shipment.

MOTOR-FLEX UNITS

Martindale Motor Flex Units are made in 7 Models — 24 Combinations. They vary from 1/10 to ½ H.P. with various motor speeds. Available in bench, pedestal or overhead suspension types.

Complete line of attachments.

METAL-WORKING SAWS

Made of 18-4-1 High Speed Steel in 4 types for Screw-Slotting, Metal-Slitting, Copper-Slitting and other cutting operations on both ferrous and non-ferrous metals.

Diameters range from 1¾" to 4" and stock tools are made with various numbers of teeth and in a wide variety of thicknesses.

Send for new 64-page catalog No. 30 covering these and many other items for maintenance, safety and production.

MARTINDALE ELECTRIC CO.
1372 Hird Avenue, Cleveland 7, Ohio

Twice the life of previous heating elements!

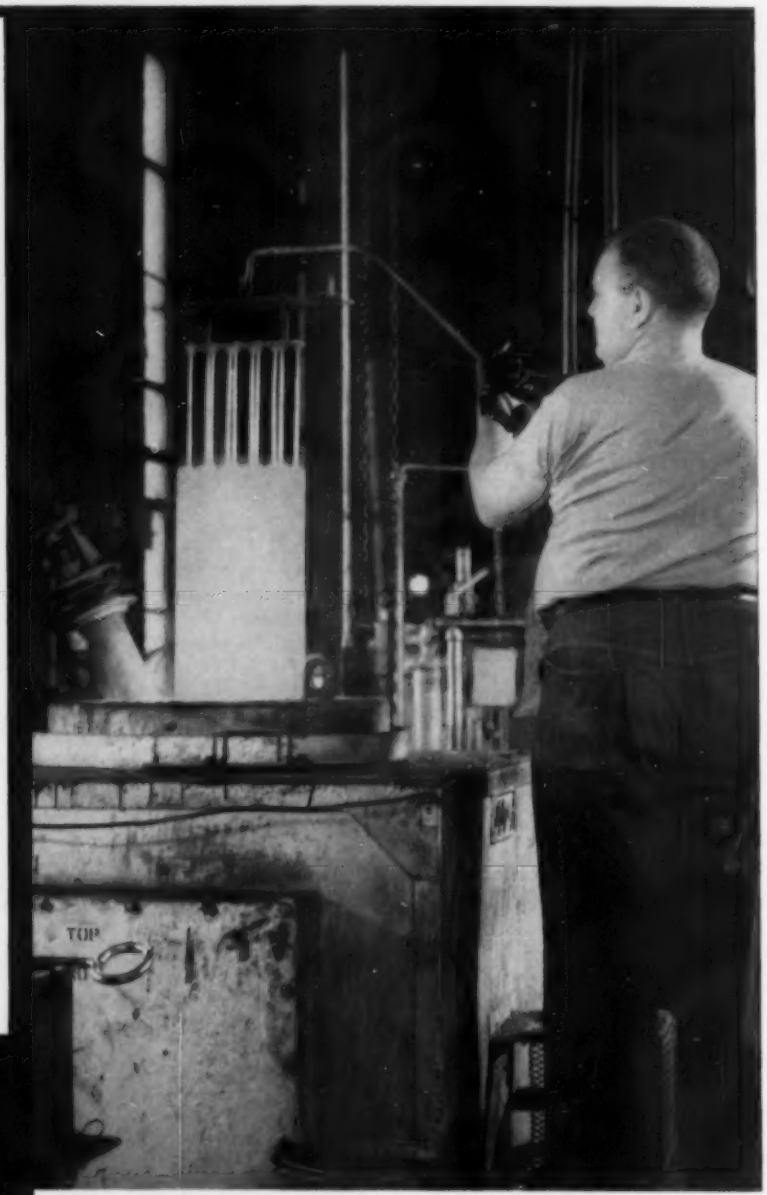
...a report on "HOT RODS" in intermittent service

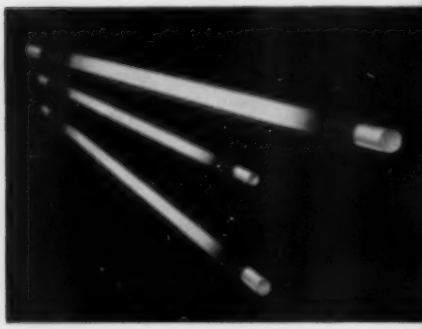
Many plants report Norton "Hot Rods" outlast other non-metallic elements by a considerable margin. Here's a case where they're lasting twice as long — in gruelling intermittent service.

This means big savings in element costs alone. You also save maintenance expense, due to less frequent changing of elements and voltage taps. And you don't have to shut down the furnace to replace elements.

Also, "Hot Rods" heat more uniformly, due to their slow, evenly matched rate of resistance increase. This helps protect product quality and maintain a smooth production flow.

The booklet, *"Norton Heating Elements,"* tells you more about how "Hot Rods" can help improve your furnace operations and cut costs. Write for your copy to NORTON COMPANY, Refractories Division, 326 New Bond Street, Worcester 6, Massachusetts.





After Hardening At 2200°F, white-hot hacksaw blades are lifted from a Lindberg hydrizing furnace in the plant of *G. W. Griffin Co.*, Franklin, N. H. — a well-known manufacturer of hacksaws. Norton CRYSTOLON* heating elements ("Hot Rods") are located in air outside the crucible which contains the protective atmosphere. Heating cycles are intermittent, the furnace being shut down each night. The "Hot Rods" in this installation have averaged twice the service life of the elements used previously.

CRYSTOLON Heating Elements, or "Hot Rods", are a typical Norton Rx — an expertly engineered refractory prescription for greater efficiency and economy in electric furnace and kiln operation. Made of self-bonded silicon carbide, each rod has a central hot zone and cold ends. Aluminum-sprayed tips and metal-impregnated ends minimize resistance and power loss. Available in standard sizes and interchangeable with your present rods.

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries

NORTON
REFRACTORIES
Engineered... Rx ...Prescribed

Making better products... to make your products better

bright and sharp. It is designed for the deburring of stamped or machined parts, grinding off sharp edges, removing tarnish, rust, and heat scale, improving surface finishes, and deburring steel and zinc.

For further information circle No. 12 on literature request card, p. 48-B.

Induction Heating Equipment

Lepel High Frequency Laboratories has announced a new line of rotary tables, index tables and conveyor belt units for automatic continuous feed in metal joining and heat treating operations. The illustration shows an application combining high frequency induction heating with the new rotary

table in the assembly of fuse plugs. The conical piece of 165° F. fusible metal is dipped into an active flux and inserted into the hollow fuse plug. This assembly is then placed into one of the 40 chromium-plated brass holders around the turntable. The fuse plugs are carried continuously through the load coil and heated to the desired temperature which is governed by the speed of the turntable. The rotating plate is interchangeable with other plates for changing from one job to another.

For further information circle No. 13 on literature request card, p. 48-B.

Degreaser

The Dawson Corp. has announced a degreasing machine which utilizes the vapors of trichlorethylene or perchlorethylene. The unit has a degreasing compartment 18 by 10 by 8 in. The vapors are generated by thermostatically controlled electric heat which boils the solvent in the degreaser. Two electrical outlets are needed, one for the 1600 watt heater and the other for a spray pump which provides a stream of solution for slush cleaning. The vapors are retained in the degreaser by a cooling coil which condenses the vapors at a predetermined level. Contaminated cleaning solution can be reclaimed by vaporizing and condensing in the storage compartment.

For further information circle No. 14 on literature request card, p. 48-B.

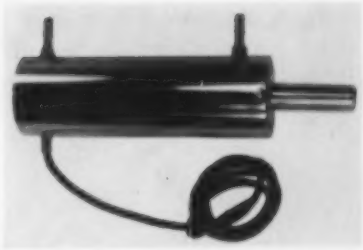
Shell Molding

The Shalco Engineering Corp. has announced the installation at National Tube Div. of a shell molding machine for pattern size 36 by 36 in. The two-station unit will produce steel castings up to 34 in. square and smaller castings arranged in multiple patterns on the two pattern plates. The unit is 18 ft. long and weighs over 4 tons. The machine incorporates hydraulic motors to invert the pattern plates and dump boxes during the investment cycle. The oven is moved back and forth for the curing cycle by means of electric power. Shell ejection is accomplished by means of two hydraulically powered ejection plates.

For further information circle No. 15 on literature request card, p. 48-B.

Ultrasonic Transducer

A new ultrasonic transducer of the stack-tool type has been announced by Alcar Instruments. The unit has been designed so that tools can be mounted on it for soldering, cutting



or other ultrasonic applications. The transducer operates at a standard frequency of 19.2±5%, input power 250 to 500 watts at 75 ohms.

For further information circle No. 16 on literature request card, p. 48-B.

Measuring Hot Gas Temperatures

A new type pyrometry instrument for measuring the temperature of hot gases in difficult situations, where the gas temperatures and surroundings are constantly changing, has been announced by Fielden Instrument Div. The instrument, called a Land suction pyrometer, provides measurement to 2900° F. It will find usage in uptakes and regenerators of open-hearth furnaces. The device forces hot gases at high velocity past thermocouple temperature-sensing elements.

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THE PRESSED STEEL CO.
Wilkes-Barre, Pa.

Diamond in the rough

This 42,000 pound Finkl FX die nearing completion at the Ladish Co., Cudahy, Wisconsin, will be utilized by that firm in drop forging 1681 pound close tolerance aircraft propeller blades. FX is but one of many Finkl steels available for forging operations, all of which are quality controlled with "built-in" characteristics required for precision production. For the proper die steels to fit your needs, ask your local Finkl representative or write for the Finkl catalog.

When you next consider hot work tooling, die blocks, or forgings, call on Finkl for "impressions that last."

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The main unit consists of a water-cooled stainless steel jacket, 6 ft. in length. A platinum thermocouple with 5 ft. of spare wire in a reel box is also part of the suction pyrometer.

For further information circle No. 17 on literature request card, p. 48-B.

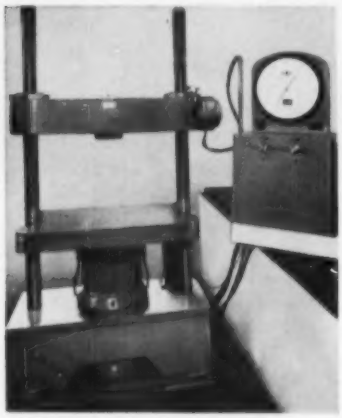
Lithium Metal

Lithium metal available in commercial quantities has been announced by Foote Mineral Co. The metal is offered in 1 lb. ingots packed under oil in sealed steel cans and typically analyzes 99.8% Li. In the metallurgical field, it is used as an alloy for nonferrous metals, and as a scavenger and degasifier in both the ferrous and nonferrous fields.

For further information circle No. 18 on literature request card, p. 48-B.

Compression Tester

A 500,000 lb. capacity compression testing machine has been developed by Tinius Olsen Testing Machine Co. Built specifically for testing complete

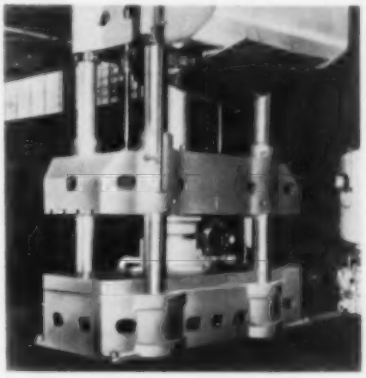


aircraft wheel assemblies, this new machine is designed so that any one of three testing ranges—full capacity, 1/5 capacity and 1/20 capacity—are instantly available without stopping the test. Load is indicated electronically on a large dial. The piston and cylinder have been designed for installation in a pit so that the compression table is at floor level within easy reach of the operator.

For further information circle No. 19 on literature request card, p. 48-B.

Sheet Metal Forming

A Marform process package unit adaptable to any conventional hydraulic press has been announced by Loewy-Hydropress Div. The pads are interchangeable to meet specific pressure and blank size requirements. A typical package unit is shown in the illustration above. Independent hydraulic system for the unit is at the right. Designed for quick changeover, the unit may be removed, if desired,



allowing the press to be used for its normal functions. The Marform process combines the economy of the rubber pad method of sheet metal forming, with the deep-drawing ability of the steel die. It is used for forming parts where surface finish is critical and the shape is complex.

For further information circle No. 20 on literature request card, p. 48-B.

Gas Pressure Switch

Minneapolis Honeywell has announced a new industrial pressure switch. It consists of an spst mercury switch actuated by a nonmetallic diaphragm. It was designed for use as a safety cutoff switch on multiple burner gas installations but can be used as a pressure controller for hazardous gases or as a differential pressure controller for nonhazardous gases. Its chief features are a sealed pressure chamber, visible switch position and control settings, protected settings, optional lockout mechanism and die cast cases.

For further information circle No. 21 on literature request card, p. 48-B.

Tensile Testing

The Cal-Testing Machine Co. has announced a new tensile testing device and fixture. Adaptable for tension, compression, or flexural testing when fitted with the proper accessories, the Cal-Tester provides a constant rate of strain and load for testing metallic or nonmetallic materials in rod, strip or sheet form. The Cal-Tester has load ranges of 1000 and 500 lb., divided into increments of 5 and 20 lb. on two 6-in. Bourdon tube gages. The unit is equipped with

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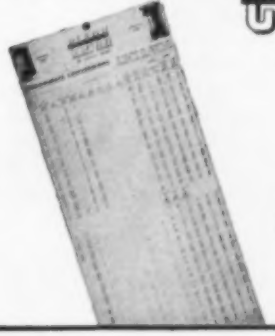

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MUELLER BRASS CO. improves LENSOMETER lower cost

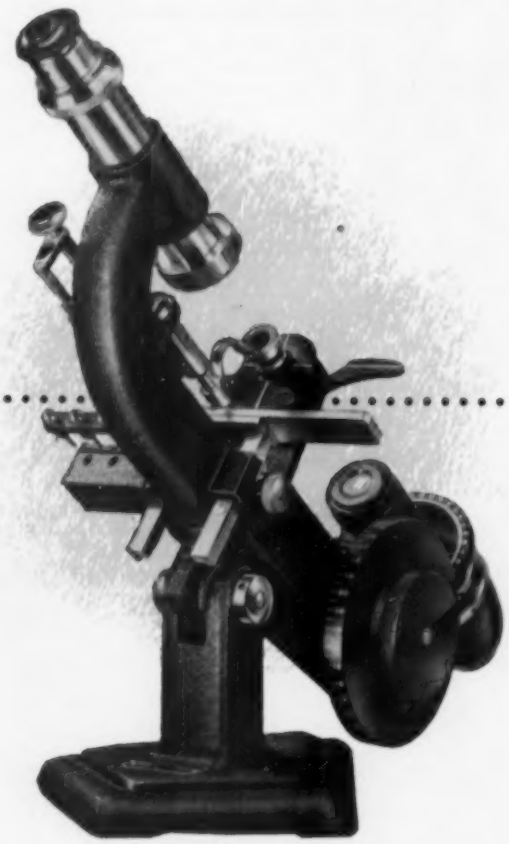
FORGED PART APPROXIMATELY ½ SIZE

Precision and extreme accuracy are vitally important functions of the Lensometer, manufactured by the Instrument Division of the American Optical Company, Buffalo, N. Y. The Lensometer is used to determine the focal strength and axis of an optical lens and, consequently, must be extremely precise in operation to provide accuracy and uniformity in lens prescriptions.

Forgings made by the Mueller Brass Co. play an important role in the construction of the Lensometer and contribute to its outstanding performance. Formerly, the body of the Lensometer was produced from *three* sand castings, but these now have been replaced by just *two* forgings. Naturally, this simplifies assembly, and the big forged bronze main support arm, shown above, along with the lens support bracket insures the constantly accurate alignment of the instrument. During the first year when forgings were used instead of castings, American Optical not only recovered the initial tooling costs but also realized considerable savings on each Lensometer produced. This is another good example of the way Mueller Brass Co. forgings can benefit a product two ways . . . better performance and lower costs. Chances are, your product can likewise be improved at a savings to you if you specify brass, bronze or aluminum forgings made by the Mueller Brass Co.

FORGING

at substantially



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Mueller Brass Co. Forgings Engineering Manual H-58565 ☐

Tuf-Stuf Aluminum Bronze Alloys Engineering Manual H-58563 ☐

600 Series Bearing Alloys Engineering Manual FM-3000 ☐

Copper Base Alloys in Rod Form Engineering Manual FM-3010 ☐

METALS AND ALLOYS REVIEW

by FRANK M. LEVY

Vice-President and Director of Research

One of our most interesting series of alloys is the group which we market under the tradename "Tuf-Stuf" . . . a group of aluminum bronze alloys with range and flexibility to meet the most demanding needs. They are high copper base alloys containing from 9% to 13% aluminum and varying amounts of iron, nickel and manganese. Being free of zinc, they are not subject to dezincification. Tuf-Stuf alloys have a low coefficient of friction, good wearing qualities, high tensile strength, high hardness and the ability to withstand heavy pounding. Some of the alloys can be hardened by heat treatment. In the harder grades, these alloys are used for heavy duty service where high compressive loads are encountered and where lubrication may be scant. Present day increases in operating speed of modern machine equipment and the economy of little or no machine "down" time has made Tuf-Stuf popular in the machine tool industry. It is used in a multitude of applications where resistance to wear is important, such as: Drill Jigs, Feed Nuts, Rollers, Cams, Collets, Gibs, Gears, Boring Bar Guides, Lead Screw Nuts and Clutch Shifter Forks. Also, because of their ability to withstand higher stresses and resist season-cracking, these alloys are ideally suited for threaded nuts and bolts and pole-line hardware.

The unusual physical properties of the Tuf-Stuf series have made it particularly useful in the chemical and allied industries. These alloys combine the strength and ductility of medium steel with high resistance to corrosion by many chemicals. Tuf-Stuf alloys will not only resist oxidation at elevated temperatures, but will also retain a greater portion of their strength and hardness at these temperatures than will the copper zinc alloys. These properties make them ideal in the aircraft industry for valve seat inserts, spark plug bushings, valve guides and propeller hub cones.

Tuf-Stuf alloys are supplied as forgings, rod or screw machine products. As forgings the grain structure can be controlled to produce parts that are strongest at points of greatest stress and strain. Relatively intricate shapes can be forged to closer tolerances than sand castings. Where appearance is a factor, a forging may easily prove more economical since a minimum amount of machining, buffing or polishing is required before finishing.

If you'd like more information about this series of alloys, drop me a line or better yet, send me your sample part or blueprint and an explanation of its use and we'll be glad to submit our recommendations.

MUELLER BRASS CO.

PORT HURON 20, MICHIGAN

178

KENTRALL Hardness Tester

MAKES BOTH Superficial & Regular Tests

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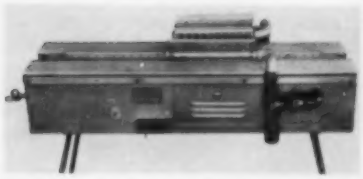

a precision shut-off valve and automatic piston check to protect it from overloading or overtravel.

For further information circle No. 22 on literature request card, p. 48-B.

Brazing

A multiflame brazing machine has been announced by Youngberg Brothers. It can also be used for tempering, annealing and hardening. The unit can be fitted into any production line. It operates on manufactured, natural or LP gas, with conventional shop airlines supplying air pressure. A regulated conveyor belt establishes production speeds. Materials move through a heating zone that can be adjusted to accept materials up to 10 in. wide and 30 in. high. Burner manifolds can be adjusted to allow angling flames properly for the most complex joinings.

For further information circle No. 23 on literature request card, p. 48-B.

Air Drier

A new mechanically refrigerated air drier which produces a constant supply of air to —110° dew point, has been announced by Murphy & Miller, Inc. It is completely automatic in

operation. The unit is available in capacities from 4 c.f.m. and up, and is shipped ready to operate after connections are made to an electrical outlet and the air supply line.

For further information circle No. 24 on literature request card, p. 48-B.

Degreasing Basket

A new basket, constructed of 16 gage corrosion-resistant Monel metal, made for use in a degreasing and annealing furnace, has been announced

THE MARK OF QUALITY

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Wheelco Instruments

Model 407 Capacitrol improves furnace control, lengthens service life of heating elements

Wheelco's Model 407 Capacitrol, with saturable core reactor, improves heat treat results and reduces equipment maintenance at Rockford Drop Forge Co., Rockford, Ill. Stepless, proportioning control of power input to an 80 kva Hevi-duty electric furnace gives even, straight-line heating, without lag or overshoot, for heat treating, annealing, and carburizing operations.

Forging hammer dies are hardened to saturation at 1850° F with improved results over the on-off control formerly used. Uniform hardening possible with Wheelco control has eliminated cracking and splitting when dies are oil quenched after heating. An added benefit of proportioning control is elimination of contactor troubles caused by on-off cycling. Also, saturable core reactor control will not permit the furnace to overshoot its control point, a major cause of damage to heating elements.

Perhaps your problems of electric furnace control can be solved by this remarkable new instrument. Call your Wheelco field engineer to get the benefit of Wheelco's long experience in control of heat processing equipment.

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VULground is now available in oil hardening and air hardening tool steels—in flats and squares, standard 18 inch and 36 inch lengths, in a wide variety of thicknesses and widths.

Vulcan's reputation for highest quality goes with every shipment of VULground gage and die steel. Depend on it *regularly*. Send now for descriptive folder and prices.

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by the Wiretex Manufacturing Co. Monel possesses resistance to corrosion by all the common organic acids and is practically free from corrosion by neutral and alkaline organic compounds. Size of the basket is 21½ by 13½ by 13½ in. Sides and bottom are of perforated Monel.

For further information circle No. 25 on literature request card, p. 48-B.

Industrial Heating

Machlett Laboratories has announced a thoriated-tungsten filament, forced-air cooled triode for industrial heating equipment in the 3 to 6 power level. It incorporates a new terminal structure and has been given increased plate voltage and power ratings for the usual dielectric heating

frequency band. Basic features of the ML-5530-H include stress-free thoriated-tungsten filament, low-loss mechanically strong grid support and rapid final seal-in by r.f.

For further information circle No. 26 on literature request card, p. 48-B.

Degreaser

A new circular vapor spray degreaser has been announced by Circo Equipment Co. The machine features unobstructed tank walls with recessed condensate trough for solvent reclamation. This trough serves as a

"Cracked" Ammonia shows tremendous cost saving and unsurpassed performance

1. —Bright Annealing—Stainless Steels, Nickel and Nickel Alloys, Beryllium Copper, Silicon Copper Alloys and Bronzes, and high and low carbon steels.
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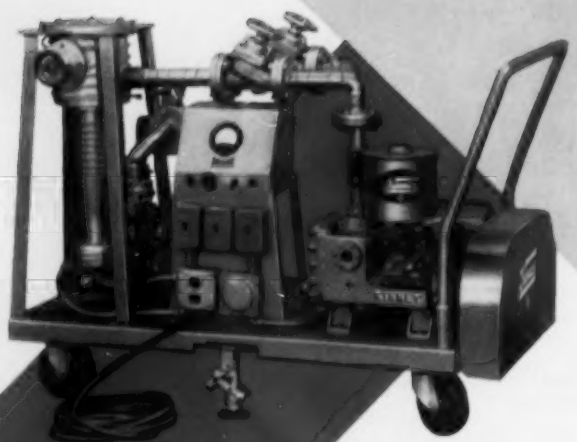
MOBILE VACUUM...

new Kinney® mobile high vacuum unit offers efficiency, flexibility!



The new Kinney Mobile High Vacuum Unit is ideal for any experimental, pilot plant, or production application where a compact, mobile station is required. This mobility feature is vital in more and more operations to cut down installation time and materials. Basic design components include: a Kinney KC-15 roughing and backing pump, a 4″ fractionating diffusion pump with 4″ baffle valve, and a Kinney KC-2 holding pump. These are mounted on a fabricated base having tubular handle, swivel casters, and caster lock . . . together with a 3 station thermocouple gauge (Ion gauge-TC gauge instrumentation optional) and a central control panel. Only utility requirements are cooling water for diffusion pump and single phase 110 volt power supply (extra long service cord supplied with unit).

Complete operational data and performance curves are available upon request. For full details contact any of our competently staffed district offices . . . in Baltimore, Charleston, W. Va., Charlotte, Chicago (La Grange), Cleveland, Detroit, Houston, Los Angeles, New Orleans, New York, Philadelphia, Pittsburgh, San Francisco, St. Louis and The International Sales Office, 90 West St., New York 6, N. Y.

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Name .....

Title .....

Company .....

Street .....

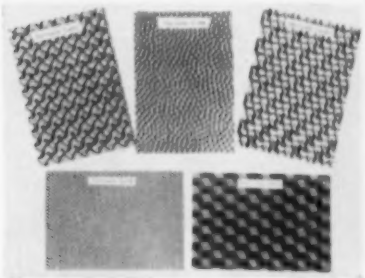
City ..... *State* .....

reservoir for distilled, pure solvent which is fed to a flexible hose and spray lance with fan-type nozzle. The degreaser is available with steam or electric heating systems.

For further information circle No. 27 on literature request card, p. 48-B.

Textured Metal

Rigidized Metals Corp. has announced the addition of four new patterns to their line of Rigid-tex metal. Maximum width is 7 to 7¾ in. Patterns include two shadow box designs,



a basket weave and a small hammered metal design. All are produced in any metal, any finish, any color, solid or perforated. An older pattern, alternating concave and convex, is now available in widths up to 36 in.

For further information circle No. 28 on literature request card, p. 48-B.

Welding Torch

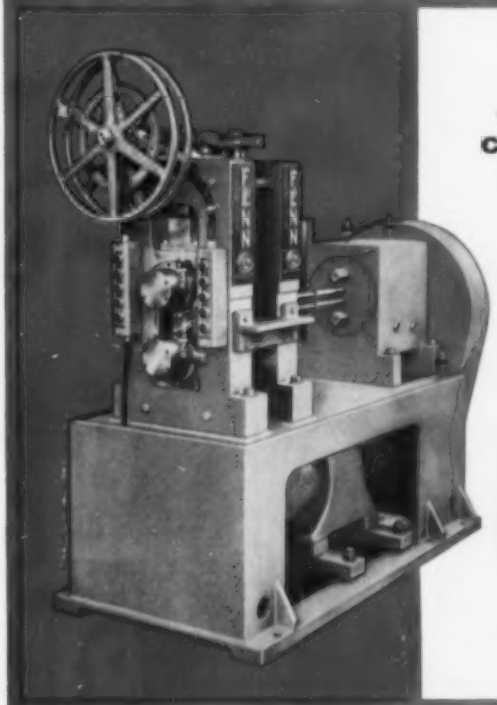
A new air-cooled torch for inert gas shielded arc welding of light metals has been announced by Linde Air Products Co. The new torch has a continuous-duty current capacity of 130 amperes (150 amperes for a reduced-duty cycle). It will join mild

steel and hard-to-weld metals like aluminum, magnesium, stainless steel, Monel, Everdur, copper, brass and high-alloy steels. It is equipped with either a 12½ or 25-ft. cable and argon hose assembly. Without cable and hose assembly, the torch weighs 4.8 oz.

For further information circle No. 29 on literature request card, p. 48-B.

NEW LABORATORY SIZE

ROLLING MILL



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PRECISION
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MODERATE COST

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APPLICATION and EQUIPMENT new literature

40. Abrasive Wheels
Operating suggestions and recommended wheels for finishing stainless. *Manhattan Rubber Div.*

41. Abrasives
18-page catalog 556 on various types of shot and grit abrasives. SAE specifications and types of cleaning and peening methods. *Cleveland Metal Abrasive*

42. Adhesive Bonding
New 8-page booklet on application techniques and precautions, advantages and limitations of adhesive bonding at room temperature. *Rubber & Asbestos Corp.*

43. Alloy Cast Iron
64-page bulletin A-71 on engineering properties and applications of Ni-Resist. Corrosion data compared with gray cast iron. *International Nickel Co.*

44. Alloy Selection
Chart to select alloy for given corrosive problem. 350 corrosives included. *Cooper Alloy*

45. Aluminum Bronze
8-page booklet on study that led to development of one-piece, nickel-aluminum bronze ship propeller. *International Nickel*

46. Aluminum Bronze
8-page booklet on aluminum bronze bearing material which is forgeable, corrosion resistant, lightweight. *Mueller Brass*

47. Aluminum Extrusions
Data on commercial aluminum extrusions. *Superior Industries*

48. Aluminum Finish
Bulletin on new invisible finish for aluminum describes Alodine No. 1000 and includes flow sheet for immersion process. *American Chemical Paint*

49. Aluminum Finishing
Bulletin F9881 on process for applying conversion coating to aluminum and zinc. *Oakite*

50. Aluminum Strip
20-page booklet on how it is made, sizes and weights of coils. Technical data on aluminum alloys used. *Scovill*

51. Ammonia Atmospheres
12-page bulletin B-52 on dissociated ammonia furnace atmospheres. *Drever*

52. Atmosphere Furnace
12-page bulletin on controlled atmosphere reciprocating hearth furnace for continuous hardening, light case carburizing, Ni-Carb ammonia-gas carburizing and other heat treating processes. *American Gas Furnace*

53. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

54. Atmosphere Furnace
Bulletin on controlled atmosphere furnace. *Industrial Heating Equipment*

55. Atmospheres
Bulletin on generator for producing pure nitrogen with a controllable hydrogen content. *Baker & Co.*

56. Automation
Two articles on automation for modern heat treating in Heat Treat Review, Vol. 7, No. 2. *Surface Combustion*

57. Bearings
20 data sheets give special properties and case histories for new Rulon oil-free bearing material. *Dixon Corp.*

58. Beryllium Copper
6-page booklet 7 on precision strip for electronics applications. Table of typical mechanical properties of beryllium copper, phosphor bronze, nickel silver, brass, gilding metal, chromium copper and stainless. *Penn Precision Products*

59. Beryllium Copper Alloys
New 8-page catalog on methods and procedures used to heat treat beryllium copper wrought and casting alloys. *Beryllium Corp.*

60. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

61. Blast Cleaning
24-page catalog 1210 on equipment and accessories for blast cleaning and dust control. *Pangborn*

62. Boiler Refractories
20-page bulletin on boiler refractories discusses basic requirements of refractories, what causes refractories to fail, various kinds of insulating firebrick. *Refractories Div., Babcock & Wilcox*

63. Boron
16-page book on boron carbide, elemental boron and other boron-rich materials. Property data, sizing of powders, manufacture, uses. *Norton*

64. Boron Additive
6-page article on use of grainal as boron-additive alloy and properties of grainal steels. *Vanadium Corp.*

65. Brazing
Bulletin 5889 on furnace and induction brazing installations and methods. *General Electric*

66. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

67. Brinell Machine
Data on semi-automatic Brinell testing machine. *Detroit Testing Machine*

68. Bronze
Folder gives tables of properties, uses, forms and other data on phosphor bronzes. *Chase Brass & Copper Co.*

69. Calibrating Machine
Bulletin 115 on calibrating system for accurate measurement of mechanical forces. *Morehouse Machine*

70. Carbon
New technical bulletin gives chemical and physical characteristics of metallurgical carbons. *Barnebey-Cheney*

71. Carbon Refractories
New catalog section on carbon products for cupola furnaces gives physical properties of carbon refractories and describes applications. *National Carbon*

39. Thermocouples
The importance of the thermocouple as an aid to metallurgical industry and research is underlined in this new booklet, "Noble Metal Thermocouples". After brief surveys of methods of high temperature measurement and of the development of the thermocouple, the booklet goes on to deal with applications of the platinum metal thermocouple – with particular reference to its use in the steel industry – and with methods of calibration. A further section covers the properties of the platinum group metals and their alloys in relation to the problems of temperature measurement, and in addition, information is given on the principal causes of deterioration of thermocouples under strain, prolonged heating at high temperatures, and contamination. *Johnson, Matthey & Co.*

72. Carbonitriding
Bulletin 241 on gas-fired radiant-tube furnace for carbonitriding and other heat treating. *Lindberg Engineering*

73. Cemented Carbides
20-page booklet illustrates and describes all styles of standard blanks, boring tools, roll turning and milling cutter blanks, throw-away inserts and others. Grade selection chart. *Firth-Loach Metals, Inc.*

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74. Centrifugal Castings
Three bulletins give metallurgical specifications for ferrous and nonferrous castings, applications and variety of castings. *Sandusky Foundry & Machine*

75. Centrifugal Castings
Folder on advantages of centrifugally cast thermalloy. *Electro-Alloys Div.*

76. Ceramic Tools
10-page report on machining steel with ceramic tools includes grinding ceramic tools, new-type tool holder, geometry of ceramic tools. *Norton*

77. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

78. Chromium Plating
4-page bulletin on new "crack-free" chromium plating process. *United Chromium*

79. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

80. Cleaner
Folder gives data on metal cleaners for use with water in still-tank or spray-washing equipment. *Solventol*

81. Cleaning
28-page catalog, B-9, on corrosion-resistant baskets, racks, crates and tanks and other fixtures for cleaning and finishing. *Rolock*

82. Cobalt Alloy
12-page booklet, "Haynes Alloy No. 25", tells of the unique properties of this cobalt-base alloy. *Haynes Stellite*

83. Coil Handling
New 28-page booklet on coil stock handling and punch press feeding equipment. *F. J. Littell Machine Co.*

84. Cold Treatment
8-page folder describes various models of industrial freezers and gives their ranges. Applications. *Webber Mfg. Co.*

85. Combustion Control
20-page booklet on combustion of various fuels and portable instruments to measure content of oxygen and combustibles. *Cities Service Oil*

86. Combustion Meters
Catalog 56-553-1 on different types of chemically operated carbon dioxide analyzers and recorders. Operation and sampling systems. *Hays Corp.*

87. Compressors
12-page bulletin 126-A on application of turbo compressors to oil and gas-fired equipment used in heat treating, agitation, cooling, drying. Performance curves, capacities. *Spencer Turbine*

88. Continuous Processing
New 6-page Bulletin 561 on equipment for continuous processing lines; punch and shear lines, including coil cars, pay-off and coiling reels, levelers, press feeds, stitchers, slitters, bridles, shears and accessory equipment. *Herr Equipment Corp.*

89. Controllers
16-page educational bulletin No. 9 gives data, operation diagrams, schematic drawings of capacitrols. *Wheelco Instruments*

90. Copper Alloys
48-page book contains tables of alloys with composition, typical uses, general, working, mechanical, electrical properties, hardness, ASTM specification numbers. *Revere*

91. Corrosion of Copper
28-page booklet B-36 discusses corro-

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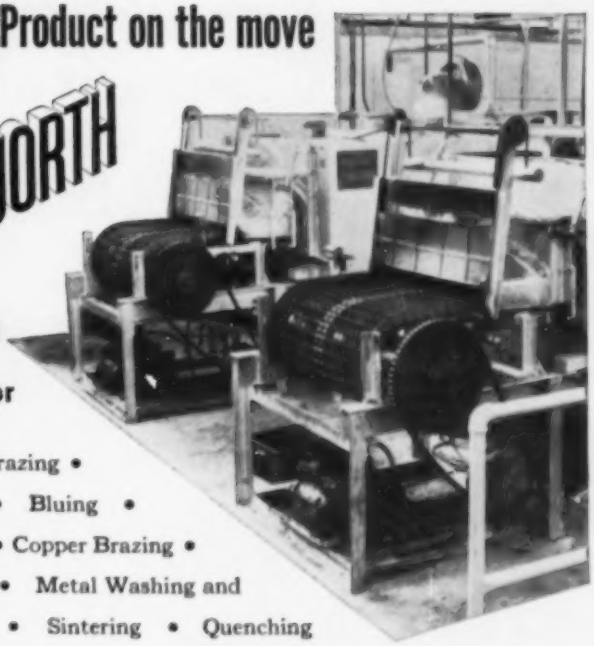

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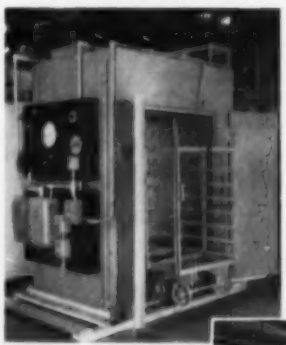

These are typical of many Rockwell recirculating ovens—standard or special—batch or continuous—electric, gas, oil or steam—engineered for top operating quality and economy.

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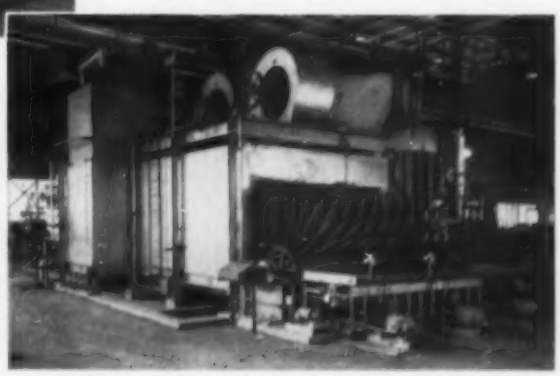

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sive attack on copper and copper alloys. Tabulation of their relative corrosion resistance. *American Brass*

92. Corrosion Protection

New 16-page bulletin on corrosion proof construction materials includes sections on corrosion proof cements, tank linings, protective coatings and others. *Atlas Mineral Products*

93. Corrosion Resistant Alloy

Data sheet compares corrosion properties of Elgiloy and stainless steel. *Elgin National Watch Co.*

94. Cutting Tools

36-page booklet analyzes and compares carbon, high speed, cast alloy and carbide tool materials. *Allegheny Ludlum*

95. Degreasing

34-page booklet on vapor degreasing. Design, installation, operation and maintenance of equipment. *Circo Equipment*

96. Demineralization

24-page article on demineralizing considers development, trends and applications of multi-bed and mixed-bed ion exchange. *Graver Water Conditioning*

97. Descaling

16-page bulletin 608 on how Rotoblast descaling machine operates, outstanding features, examples of its use. *Pangborn*

98. Descaling Process

8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

99. Descaling Stainless Steel

Bulletin 25 on descaling stainless steel and other metals in molten salt. *Hooker Electrochemical*

100. Dust Control

24-page bulletin 98 on dust control describes and diagrams systems and their operation, gives capacities of filters and kinds of dust which may be controlled. *W. W. Sly Mfg. Co.*

101. Electric Furnace

Bulletin on box-type, pre-heat and hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

102. Electric Furnaces

36-page brochure on electric arc furnaces for steel melting. Various designs and special features for production and pilot sizes. *Swindell-Dressler*

103. Electric Furnaces

Brochure on electric heat treating, melting, metallurgical tube, research and sintering furnaces. *Pereny Equipment*

104. Electric Melting

Bulletin 527 on compact arc furnace. Melt time and power consumption for four alloys. *Detroit Electric Furnace*

105. Electrodes

22-page booklet on aluminum bronze and phosphor bronze arc welding electrodes, filler wire and coil wire gives general description and property data for each type. *Metal and Thermit*

106. Electropolisher

Bulletin on theory and practice of electrolytic polishing of metallurgical samples. Description of electropolisher. *Buehler*

107. Expanded Metal

4-page folder on small-mesh expanded metal. Weights, dimensions for various gages and strands. *Penn Metal Co.*

108. Fasteners

New catalog, No. 58, shows cold forged specialties, special rivets, screws and such secondary operations as reheading, special threading, pointing, turning, swaging. *Hassall*

109. Ferro-Alloys

32-page book tells how ferro-alloys are made and how they are used. *Electro Metallurgical Co.*

110. Filters

32-page booklet on filters, mixers, pumps and tanks for liquid processing. *Alsop Engineering*

111. Finishing

16-page bulletin 51 on handling, metal cleaning, precision finishing and baking equipment. *Despatch Oven*

112. Flame Hardening

20-page booklet on precision flame hardening machine with electronic control. Details of operation and applications. *Cincinnati Milling Machine*

113. Flame Machining

New booklet on precision flame machining of large sprockets and gears. *Seaman-Andwall Corp.*

114. Flame Plating

16-page booklet lists advantages, properties, specifications of flame-plated tungsten carbide coating. *Linde*

115. Flow Meter

New 6-page Bulletin 301 on Transometer and how it is used for flow, ratio and combustion control, for multiple fuel totalization and for interchangeable control in fuel switch over. Liquids it will handle. *Askania Regulator*

116. Flow Meters

Bulletin 201 on flow meter for gas used in heat treating. *Waukee Eng'g*

117. Forgings

94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

118. Forgings

6-page brochure on cored forgings of aluminum and other nonferrous metals. Advantages. *Weatherhead Co.*

119. Formed Shapes

New 26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

120. Furnaces

New catalog on standard and special furnaces and ovens to 3000° F. *L & L Mfg. Co.*

121. Furnaces

High-temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

122. Furnaces

Brochures on pot furnaces, nitriding, austempering, and martempering and salt baths. *A. F. Holden*

123. Furnaces

Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

124. Furnaces

Bulletin 424R on gas, oil, and electric revolving retort furnaces for annealing, hardening, drawing. *W. S. Rockwell Co.*

125. Furnaces

32-page catalog of industrial equipment includes furnaces and furnace accessories, special valves, mechanical equipment, materials handling equipment. *Salem-Brosius*

126. Furnaces

Folder giving drawings, dimensions, capacity, Btu. required for drawing, annealing, forging. *Gas Machinery*

127. Furnaces, Heat Treating

12-page bulletin on conveyor furnace, radiant tube gas heated, oil or electrically heated. *Electric Furnace Co.*

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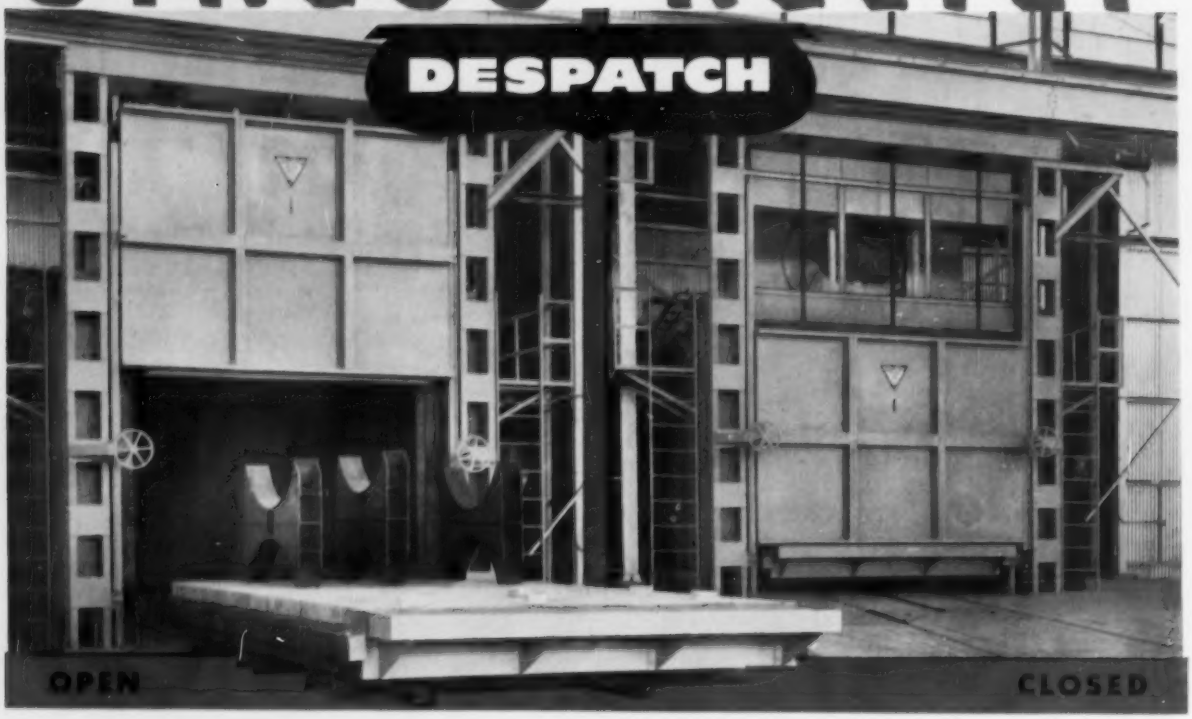

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128. Gamma Radiography
16-page bulletin describes isotopes used, equipment and applications. *Budd Co.*

129. Gamma Ray Sources
24-page booklet on portable gamma ray projectors, using cobalt 60, cesium 137, iridium 192. Operation and construction features. *Metal & Thermit Corp.*

130. Gas Analyzers
Data sheet 10, 15-8a on thermal conductivity type analyzers with recorders and controllers. *Minneapolis-Honeywell*

131. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

132. Graphite
New 6-page bulletin on graphite for atomic energy applications. *National Carbon*

133. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

134. Grinding Machines
Folder on grinders tabulates horsepower, wheel size, speeds and sizes for various models. *Grinding and Polishing Machinery Corp.*

135. Grinding Wheels
New 36-page booklet on mounted wheels gives maximum operating speeds in 8 tables. Rules for safe and efficient operation. *Grinding Wheel Institute*

136. Hardness Tester
Bulletin on Impressor portable hardness tester for aluminum, aluminum alloys and soft metals. *Barber-Colman*

137. Hardness Tester
New bulletin on Wolpert-Gries Micro-Reflex hardness tester for loads from 10 to 3000 g. *Gries Industries, Inc.*

138. Hardness Tester
Bulletin on how to test large gears with portable Brinell tester. *King Tester*

139. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

140. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

141. Hardness Testers
20-page bulletin on models, applications and how to use superficial hardness testers. *Wilson Mechanical Instrument*

142. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage International*

143. Hardness Testers
20-page book on hardness testing by Rockwell method. *Clark Instrument*

144. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

145. Heat Treating
Bulletin 14-T on ovens for heat treatment of aluminum and other low-temperature processing. *Young Bros.*

146. Heat Treating
24-page booklet on how to plan a tool room heat treating department gives several layouts of furnaces and auxiliary equipment. *Lindberg Engineering Co.*

147. Heat Treating Ammonia
24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

148. Heat Treating Belts
Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

149. Heat Treating Belts
New 16-page booklet on selection of steel processing conveyor belts gives complete specifications. *Colorado Fuel & Iron*

150. Heat Treating Fixtures
24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

151. Heat Treating Fixtures
12-page bulletin on wire mesh baskets for use in heat treating and plating of metals. *Wiretex*

152. Heat Treating Fixtures
Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

153. Heat Treating Furnaces
12-page booklet on various heat treating furnaces contains chronology of advances in heat treating furnaces. *Holcroft*

154. Heat Treating Furnaces
32-page catalog on high-speed gas furnaces for heat treating carbon and alloy steels; also pot furnaces for salt and lead hardening. *Charles A. Hones*

155. Heating Elements
24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

"How to make better use of Chromel-Alumel thermocouples!"

That's the subject covered in detail by this new basic guide to more accurate temperature measurement. It gives complete specifications on these exclusive Hoskins alloys . . . clearly states the Accuracy Guarantee applicable to both thermocouple and lead wire grade material. It lists temperature-millivolt equivalents for Chromel vs Alumel . . . explains standardization procedures, and tells how best to test "unknown" wires. What's more, it contains much useful application data to help you make more and better use of Chromel-Alumel thermocouples. Yes, if you're interested in accurately controlling temperatures, this manual is meant for you. Send for it today!

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SHELL VOLUTA OIL 23"

says Garland Wilcox, Chief Metallurgist
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...the story of a profitable change

WALLACE BARNES COMPANY and steel springs have "gone together" for nearly a century. Most of today's output is in SAE 1075 or 1095 steel.

Because the quenching operation is so important to the life of springs, the Wallace Barnes laboratory decided to test its regular quenching oil against some of the newer products, including Shell Voluta Oil 23. This is what they found:

Shell Voluta Oil 23 showed a superior quench rate, with correct hardening and relative freedom from distortion. It drained more rapidly from the quenched parts, reducing dragout loss. It washed off more completely in the alkaline cleaner; it reduced flaming, and cut down on the oil baked to parts.

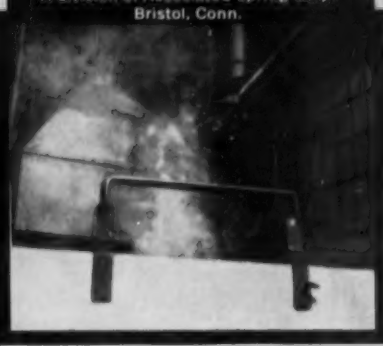
Wallace Barnes reports that this oil has almost eliminated trouble with "slack-quenched parts," and that heavier stock now goes through without special handling. So . . . Shell Voluta Oil 23 has replaced the former quench oil in all tanks of the spring hardening departments, serving salt pot lines and shaker hearth furnaces.

We'll be glad to provide full information on Shell Voluta Oil 23.

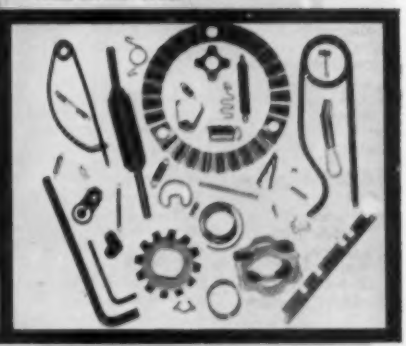
WALLACE BARNES CO.
A division of Associated Spring Corp.
Bristol, Conn.

Photos courtesy "STEEL"

Shaker hearth furnaces automatically dump parts into Shell Voluta Oil 23, then remove and drain them.



Flat springs at austenitizing temperature get a fast quench in Shell Voluta Oil 23.



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156. High-Alloy Castings
16-page bulletin, No. 3354-G, gives engineering data concerning castings used for resisting high temperatures, corrosion and abrasion. *Duraloy Co.*

157. High-Temperature Alloys
Booklet "Keep Operating Costs Down When Temperatures Go Up." *International Nickel*

158. High-Temperature Steels
87-page book on factors affecting high-temperature properties. 45 pages of data on tensile, creep and rupture properties of 21 high-temperature steels. *U. S. Steel*

159. High-Tensile Steel
Bulletin on nickel-copper steel of low-alloy, high-strength type. *Youngstown Sheet and Tube*

160. Impact Testing
Bulletin on machine for Izod, Charpy and tension testing. *Riehle*

161. Induction Furnace
New 4-page folder on combination induction melting and holding furnace and automatic pouring unit. *Ajax Engineering*

162. Induction Furnaces
Reprint R40 on semi-continuous casting of aluminum billets. *Ajax Engineering*

163. Induction Heating
8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

164. Induction Heating
Folder on high frequency induction heating for heat treatment, joining and hot forming. Charts on current penetration in steel. *Magnethermic*

165. Induction Heating
12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

166. Induction Heating Control
New Bulletin HT-1 on automatic temperature control for induction heating equipment. Types of control, components of induction heaters. *Minneapolis-Honeywell*

167. Industrial Heating
New booklet on process heating operations for light metals. *Michigan Oven Co.*

168. Instruments
20-page booklet on Hilger optical instruments including absorptiometer, spectrophotometer, comparator, spectrographs, microscopes. *Jarrell-Ash*

169. Insulation
New 20-page catalog on thermal insulations and refractories for application at −400° F. to +3000° F. Composition, physical and thermal properties. *Johns-Manville*

170. Iron Powder
8-page booklet tells of new type B iron powder. Tables give compressibility, density, green strength and other properties before and after sintering for various mixes. *Scrub Oaks Mine, Alan Wood Steel Co.*

171. Joining Stainless
24-page booklet on various welding methods, soldering, brazing, flame cutting and arc cutting of stainless. *Crucible Steel*

172. Laboratory Equipment
Bulletin on high-purity graphite powder, funnels, crucibles, boats. *United Carbon Products*

173. Leaded Steel
8-page bulletin gives chemical composition, mechanical properties and case studies showing machining production rates of Ledloy, lead bearing steel. *Ryerson*

174. Leaded Steel
Folder on lead-bearing, cold finished bars which machine about 80% faster than B1113. *LaSalle Steel*

175. Leaded Steel
8-page booklet on production of lead treated steels, their advantages and case histories of their use. *Copperweld Steel*

176. Low-Alloy Steel
60-page book on high strength low-alloy steel, properties, fabrication and uses. *U. S. Steel*

177. Low-Melting Alloys
New folder lists 63 uses for these alloys. *Cerro de Pasco*

178. Low-Temperature Brazing
Bulletin 72 contains many designs for brazing. *Handy & Harman*

179. Lubricant
Bulletin 425 on colloidal dispersions for use in metal casting. Best formulas for achieving high lubricity and wetting action. *Acheson Colloids*

180. Lubricant
Bulletin 103A on fringe area lubrication with molybdenum disulfide lubricants

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for extreme bearing pressures and all temperatures. *Alpha Molykote*

181. Lubricants
8-page booklet on colloidal greases, forging compounds, hydraulic concentrate and others. *Grafo Colloids*

182. Lubrication
New, 20-page lubrication guide for all types of Waterbury-Farrel machinery. *Waterbury Farrel*

183. Machining Costs
12-page "Relation of Machining Time to Material Cost". Comparative machinability costs per ton for eleven steels. *La Salle Steel*

184. Malleable Iron
Reprint 51-B on metallurgy, treatment and heat treated properties of malleable iron. *Surface Combustion*

185. Melting Furnaces
28-page catalog on Heroult electric melting furnaces. Types, sizes, capacities, ratings. *American Bridge*

186. Melting Guide
Selector guide for heating equipment and control for solder, tin and lead melting. *General Electric Co.*

187. Metal Cutting
8-page booklet on friction, abrasive, cut-off and long cut saws. *Ty-Sa-Man Machine*

188. Metal Cutting
64-page catalog No. 29 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

189. Metallograph
12-page book on desk-type metallograph. *American Optical*

190. Metallographic Equipment
12-page catalog E-29 describes bright-field equipment for visual observation and photography. *Bausch & Lomb*

191. Metalworking Machines
New 44-page catalog on forming, cutting, punching and notching operations on medium and light-weight metals. *O'Neil-Irwin Mfg. Co.*

192. Microhardness Tester
Bulletin describes the Kentron microhardness tester. *Torsion Balance Co.*

193. Microscopes
Catalog on metallograph and several models of microscopes. *United Scientific*

194. Molybdenum
72-page book gives data on unalloyed molybdenum and four arc-cast alloys. Several pages of references. *Climax Molybdenum*

195. Molybdenum
24-page booklet gives physical and chemical property data on molybdenum powders, wire, alloys. *Sylvania Electric*

196. Nickel Alloys
40-page book gives corrosion, physical and mechanical properties of Hastelloy alloys; 13 pages of fabrication data. *Haynes Stellite*

197. Nickel Plating
Booklet on bright nickel plating process. *United Chromium*

198. Nitriding
Data on process for nitriding stainless steel. *Standard Steel Treating*

199. Nitriding Furnace
Bulletin 646R on carburizing and nitriding furnace giving atmosphere circulation to 1850° F. *Hevi Duty*

200. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

201. Nondestructive Testing
8-page booklet on cost savings realized through nondestructive testing. *Magnaflux Corp.*

202. Nondestructive Testing
Data on new nondestructive thickness tester. *Unit Process Assemblies*

203. Nonferrous Alloys
Bulletin 154 with chart showing chemical analyses, and properties. Current U.S. Navy, Federal, Military, SAE and ASTM specifications. *Shenango-Penn Mold Co.*

204. Nonflammable Rust Preventive
Bulletin on rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

205. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

206. Openhearths
Brochure on modern openhearth design and construction. *Loftus*

207. Ovens
Bulletin 100 on laboratory and production ovens. Engineering, construction and control features. *Despatch Oven*

208. Paint Adhesion
New 6-page pamphlet on line of phosphating materials. Includes phosphating reference chart for solving paint adhesion problems. *Turco*

209. pH Measurement
New bulletin on instrumentation for pH measurement and automatic control. *Bristol*

210. Photomicrography
Catalog E-210 on sliding base, high or low power photomicrographic equipment. *Bausch & Lomb*

(*Continued on page 48A*)

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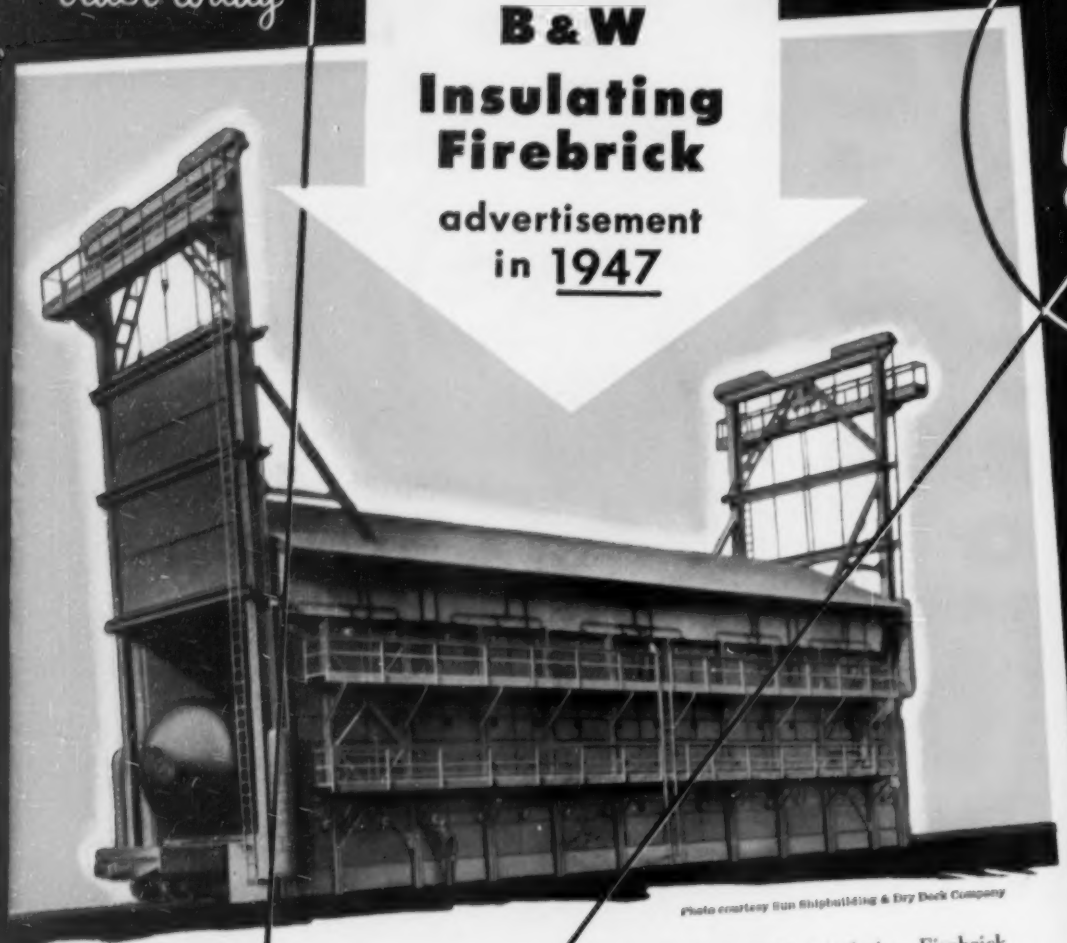

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(Continued from page 47)

211. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

212. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

213. Plastic Tools
Bulletin on how tooling compounds based on epoxy resins are used in jigs, fixtures, forms, patterns, dies. *Bakelite Co.*

214. Plating
List of chemicals and precious metal catalysts for the preparation of plating baths. *J. Bishop & Co. Platinum Works*

215. Plating
New edition of 12-page guide to power conversion rectifiers. *Bart Messing Corp.*

216. Portable Recorder
Bulletin 60-100 on instrument for recording any measurement that can be converted to a change in resistance of d.c. millivoltage. *Thermo Electric*

217. Powder Cutting
New 4-page folder lists applications of powder scarfing, gouging, lancing and washing. *Hoeganaes Sponge Iron Corp.*

218. Powdered Metals
Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. *New Jersey Zinc*

219. Precision Casting
12-page book on alloy selection and design for precision casting. *Arwood Precision Casting*

220. Pyrometer
Catalog 45 on micro-optical pyrometer gives outstanding features, operating procedure and applications. *Pyrometer Instrument*

221. Pyrometer Calibration
"Pyrometer Thermocouple Calibration Data" includes tables of data released by National Bureau of Standards. *Bristol Co.*

222. Pyrometers
Bulletin, "Temperature Indications", on basic facts about pyrometry and line of pyrometers. *Illinois Testing Labs.*

223. Quenching
New catalog on two small self-contained quenching units. *Bell & Gossett*

224. Quenching
64-page book tells what happens when steel is heated and cooled, describes quenching media, quenching practices, interrupted quenching and cooling methods. *E. F. Houghton*

225. Quenching Oil
New Bulletin 45 on quenching oil treats mechanism of quenching and explains how Sunquench 78 aids. *Sun Oil*

226. Quenching Oils
8-page booklet on quenching oil gives cooling curves, hardnesses obtained. *Shell Oil Co.*

227. Radiamatic Pyrometers
Catalog 9301 on four types of radiation detectors for measuring temperatures from 125 to 7000° F. *Minneapolis-Honeywell*

228. Radiography
18-page bulletin on materials and accessories for radiography. Density curves for four types of films. *X-Ray Div., Eastman Kodak*

229. Rare Earths
8-page Progress Report Number 1, "Rare Earths in Iron and Steel Melting". *Molybdenum Corp.*

230. Refractories
24-page booklet on insulating firebrick and cements for use to 3000° F. Shapes, design, suspended arch and wall construction discussed. *Armstrong Cork Co.*

231. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

232. Rolling Mills
Catalog on line of machines for rolling ferrous and nonferrous metals gives descriptions and lubrication and maintenance instructions. *Fenn Mfg. Co.*

233. Salt Bath Furnaces
Data on salt bath furnaces for batch and conveyorized work. *Upton*

234. Sand Blasting
New 4-page bulletin 1256 on sand blasting machines for cleaning, deburring, surface preparation. *Leiman Bros.*

235. Sand Control
32-page book on defects and troubles in foundry and how to remedy through sand control. *Claud S. Gordon Co.*

236. Saw Blades
Selector for hand or power blades tells which blade to use for various alloys and shapes. *Henry Disston*

237. Shear
Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals, either hot or cold. *Hill Acme Co.*

238. Shell Molding
6-page brochure on shell mold casting of copper-base alloys describes how it is done and applications. *Aurora Metal Co.*

239. Shell Molding
8-page booklet on silicones for the shell molding process describes three different products. *Silicones Div., Union Carbide and Carbon Corp.*

240. Shell Molding
16-page booklet on resin-coated sand for shell molding discusses equipment, coating techniques and production of blown shell molds and cores. *Plastic Div., Monsanto Chemical Co.*

241. Silver Brazing
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

242. Silver Brazing
Series of eight technical bulletins on silver brazing. Joint strength, design, stress analysis, heat treatment, fluxes. *Handy & Harman*

243. Sodium
40-page booklet on handling metallic sodium gives typical sodium using processes, equipment installation, recommendations for pumping and instrumentation. *U.S. Industrial Chemicals*

244. Solvent Cleaning
16-page booklet on how to use solvent detergents for removing carbon, grease, dirt, paint. *Oakite Products*

245. Specification Key
Guide to Government specifications for phosphatizing, rust proofing and paint bonding chemicals. *American Chemical Paint*

246. Spectrograph
New 8-page catalog on performance and applications of Spec-Lab industrial spectrograph. *Jarrell-Ash*

247. Stainless Castings
20-page booklet shows how they are made, property and size data, typical applications. *Crucible Steel*

248. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws,

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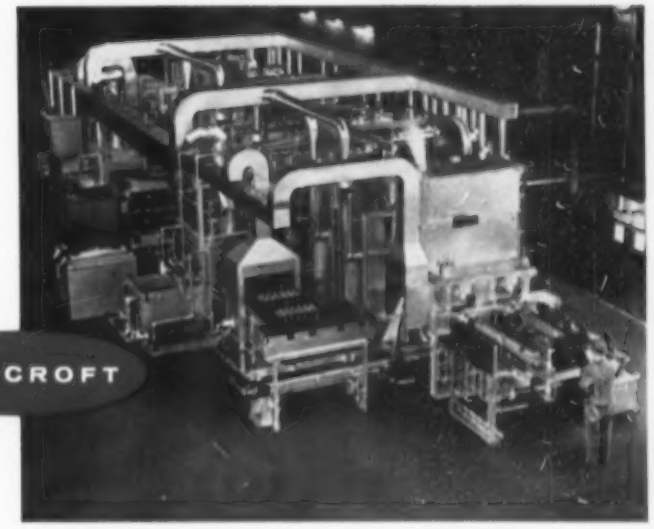

LET'S TALK

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Controlled atmospheres protect the stock while it is being treated and help produce the desired finish to the parts. Scale and decarburization are eliminated. Stock in the furnace chamber is surrounded by a gas atmosphere which excludes all air and products of combustion.

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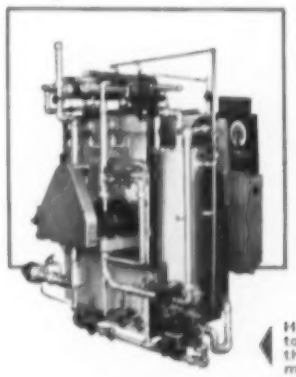
Advances like these are typical of the scope of Holcroft activities—proof that you can get right answers without prejudice. Insist upon a Holcroft quotation as your first step when you have a heat treat problem. *You'll save!*



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sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

249. Stainless Steel
Data sheet on Type 301 gives physical properties, corrosion and oxidation resistance, mechanical properties. *Allegheny Ludlum*

250. Stainless Steel
40-page Design Handbook gives properties, specifications, applications, design data on springs. *Alloy Metal Wire*

251. Stainless Steel
Slide chart. Set top at a certain fabricating operation, bottom shows rating of each standard grade. On reverse side, heat treating and corrosion data are given. *Carpenter Steel*

252. Stainless Steel
36-page bulletin on effect on properties of processing at different temperatures. *International Nickel*

253. Stainless Wire
Data on type 302 stainless wire. Tensile strength, sizes and shapes. Relaxation at elevated temperatures. *Webb Wire Div., Carpenter Steel*

254. Steel 52100
Data sheet on high-purity 52100 steel, made by vacuum melting. *Vacuum Metals*

255. Super High Speed Steel
Folder on molybdenum, 8% cobalt high speed steel for use at speeds 20 to 25% greater than with ordinary high speed steel. Heat treatments. *Firth Sterling*

256. Tanks and Linings
16 pages of data on tanks and corrosion-resistant linings for cleaning and plating solutions. *Chemical Corp.*

257. Temperature Controller
Specification Sheet S1010-1 on electronic temperature controller gives specifications and uses. *Minneapolis-Honeywell*

258. Test Specimens
Data on machine for cutting test specimens to ASTM specifications. *Sieburg Industries*

259. Testing Instruments
16-page bulletin on portable recorders, voltmeters and ammeters, surface roughness scales and other electric testers. *General Electric*

260. Textured Metal
16-page booklet on advantages and applications of textured metal. *Rigidized Metals*

261. Thermocouple Alloys
20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

262. Thermocouple Data
New bulletin F-5228-3 on construction and application of thermocouples and radiation detectors to industrial control. How to check, make, select and size thermocouples. *Wheelco*

263. Tin
20-page booklet describes mining of tin and its present use by American industry. *Malayan Tin Bureau*

264. Titanium
8-page bulletin features opportunities in design, applications, corrosion ratings of titanium. *Mallory-Sharon Titanium*

265. Tool Steel Brand Chart
Wall chart listing over 300 popular tool steels by types. *Vulcan Crucible Steel Co.*

266. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter", analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

267. Tool Steel Heat Treat
Bulletin 1147EE on electric furnace for heat treatment of high speed tool steel. *Hevi Duty*

268. Tool Steel Selector
Twist the dial of the 9-in. circular selector and read off the tool steel for your application. *Crucible Steel*

269. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

270. Tubing
52-page "Handbook of Seamless Steel Tubing". 26 pages of data. *Timken*

271. Tubing
Bulletin on aluminum preassembled refrigerator tubes. *Wolverine Tube*

272. Ultra Strength Steel
Results of three year research and test program evaluating properties of Type 4340 steel for aircraft structures. *International Nickel*

273. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

274. Ultrasonic Testing
Data folder describes instruments using ultrasonics for various tests—immerscope, "B" scan and flaw recorder. *Curtiss-Wright*

275. Vacuum Calculator
Slide rule for quick calculation of data necessary in vacuum engineering and processing—for instance, pump capacities and time to reach given vacuum. Pertinent conversion tables on back. *F. J. Stokes Machine*

276. Vacuum Metallurgy
Information memo describes the high-vacuum technique and pumping systems. *Consolidated Vacuum Corp.*

277. Vacuum Pump
4-page bulletin on small, air-cooled, compound, high-vacuum pumps. *Kinney Mfg.*

278. Welding Electrodes
84-page pocket-size booklet describes characteristics, coating, sizes of various electrodes and compares them with standard designations and other electrode brand names. *Harnischfeger*

279. Welding Electrodes
50-page book on electrodes of stainless, mild and high-tensile steels, cast iron, non-ferrous alloys, low-hydrogen and hardfacing compositions. *Air Reduction*

280. Welding Equipment
12-page bulletin 156 on special and standard resistance and arc welding equipment. *Acro Welder Mfg.*

281. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

282. Wire Cloth
84-page booklet on applications, meshes, baskets, filters. *Cambridge Wire Cloth*

283. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

284. Zinc
32-page booklet on zinc's role in controlling corrosion tells why zinc does not corrode easily, describes zinc coatings and applications of galvanized steel. *American Zinc Institute*

JULY, 1956

1	25	49	73	97	121	145	169	193	217	241	265
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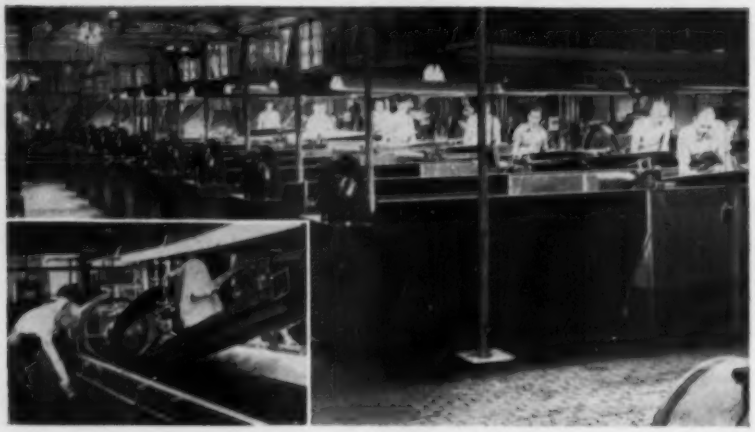
Case Studies:
NONDESTRUCTIVE TESTING SYSTEMS

AUTOMATIC AND HIGH SPEED MAGNAGLO UNIT inspects and processes steam turbine blades. By providing two-directional magnetization at the same time, it reveals cracks in any direction in a single "pass". An ideal method for lower cost, higher speed inspection needs.



Specially designed Magnaflux units tilt for inside-outside inspection of hollow steel propeller blades.

How Lower Production Costs Can Result From "Customized" Testing

Nobody expects to find defective propeller blades at 20,000 feet. Propeller manufacturers must, and do, discover even the tiniest flaws during manufacture and before their products ever leave the ground. A battery of specially designed Magnaflux units insures defect-free production at the Wright Aero Corp. New Jersey propeller plant.

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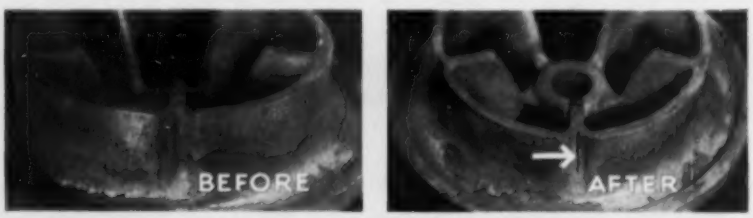
Magnaflux methods detect cracks, seams, porosity and other minute defects during the production process. By evaluating M findings, the proper corrective steps are taken to eliminate early defects. Substantial savings result from increased production, doing away with further processing effort on faulty parts, and from reduced scrap losses.

If you're "up in the air" regarding defects in critical components, Magnaflux builds and sells nondestructive test equipment to meet your exact production-line or sample test needs. Or, if your operation requires only occasional reliable testing, why not investigate our Commercial Inspection Service, available on a low-cost basis in most major industrial communities?

For detailed information regarding either service, write today, or contact one of our nearby offices for a personal get-together with an experienced Magnaflux field engineer.

INSPECTING MAGNESIUM CASTINGS — Inspection, as such, cannot produce a better product. However, by translating Zyglo indications into corrective measures the foundry can produce castings which meet the needs of their customers. Zyglo fluorescent penetrant inspection detects such flaws as cold shuts, cracks, blows, shrinkage and dross in non-ferrous magnesium or aluminum castings.



HOW INVISIBLE FORCE DETECTS MECHANICAL DEFECTS

M nondestructive testing is based upon simple magnetic principles. A part to be tested is first magnetized—then magnetic powders or fluorescent particles in oil are applied. Surface defects cause a break in the magnetic field—local magnetic poles cause particles to be held on part to mark extent of defect. Above—a Magnaflux indication on grey iron casting.

HALLMARK OF QUALITY IN NONDESTRUCTIVE TEST SYSTEMS

Write for complete details concerning any of the above case studies, (excerpts from MAGNAFACTS), or ask for our new booklet on Lower Manufacturing Costs.

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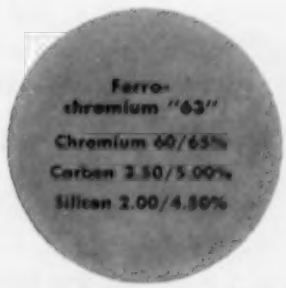

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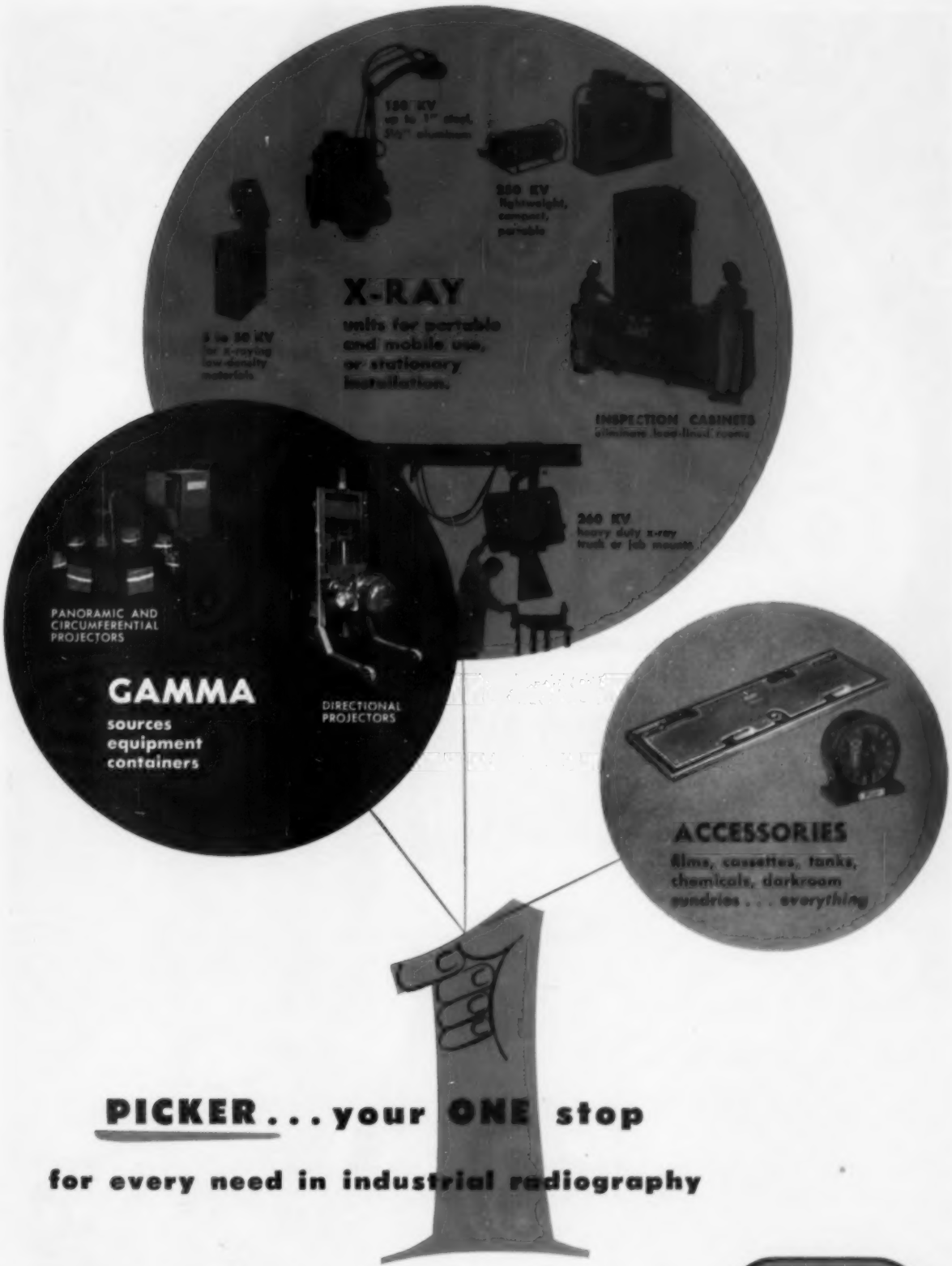

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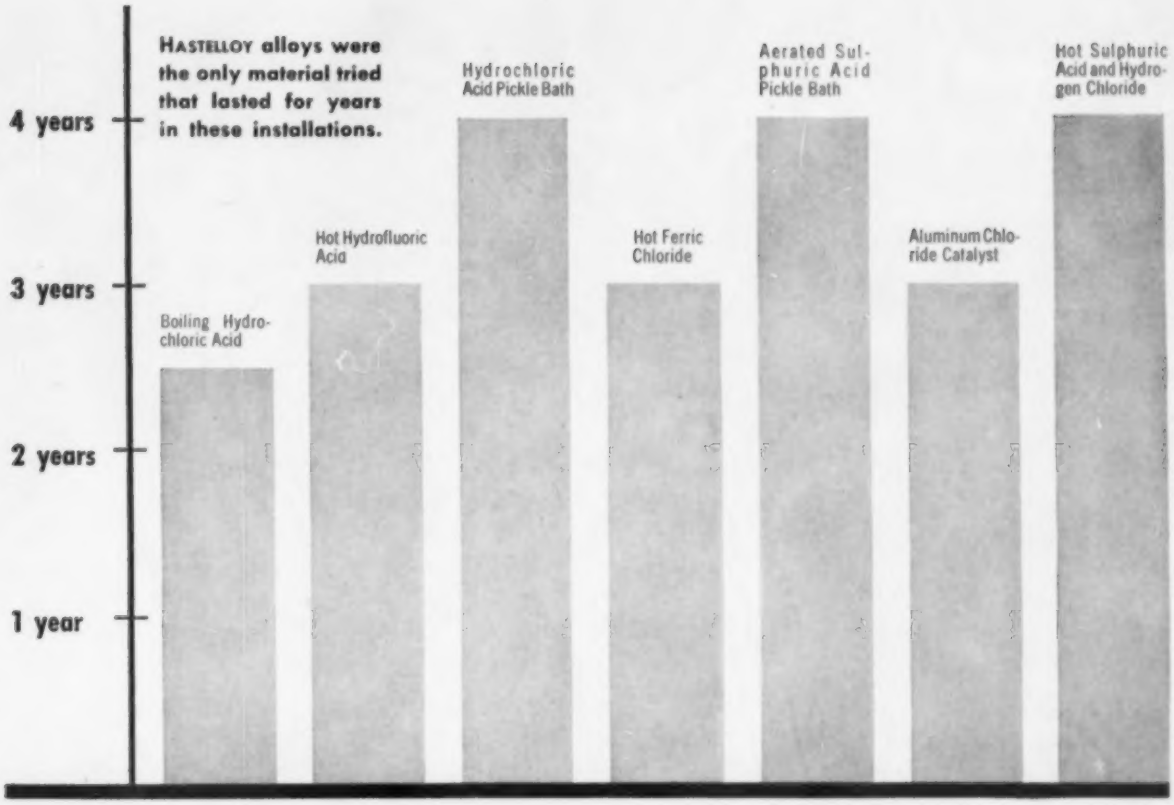
HASTELLOY alloys were the only material tried that lasted for years in these installations.
4 years
3 years
2 years
1 year
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Hot Hydrofluoric Acid
Hydrochloric Acid Pickle Bath
Hot Ferric Chloride
Aerated Sulphuric Acid Pickle Bath
Aluminum Chloride Catalyst
Hot Sulphuric Acid and Hydrogen Chloride

HASTELLOY Alloys *last for years under severe corrosive conditions*

These graphs were drawn from data on actual installations of HASTELLOY alloys in severe corrosive media. No other material tried lasted more than six months in most of these installations, some considerably less than this. HASTELLOY alloys lasted for years.

Use of HASTELLOY alloys saved time, money, and production time in all the installations. The graphs do not tell the entire story by any means. Some of the parts made of HASTELLOY alloys were still going strong when the data were obtained. In some, corrosion was complicated by abrasion, impact, and the presence of contaminants.

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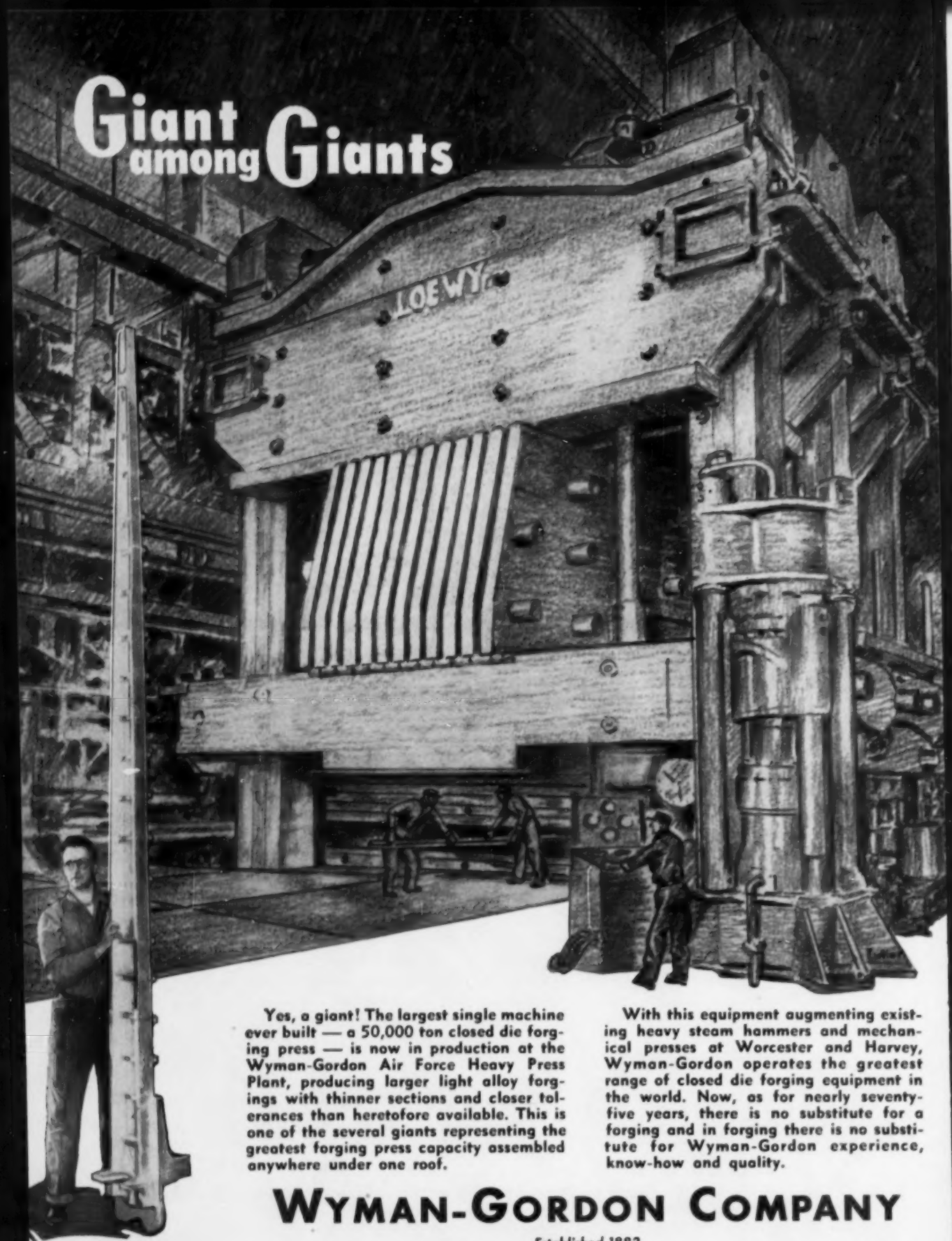

Yes, a giant! The largest single machine ever built — a 50,000 ton closed die forging press — is now in production at the Wyman-Gordon Air Force Heavy Press Plant, producing larger light alloy forgings with thinner sections and closer tolerances than heretofore available. This is one of the several giants representing the greatest forging press capacity assembled anywhere under one roof.

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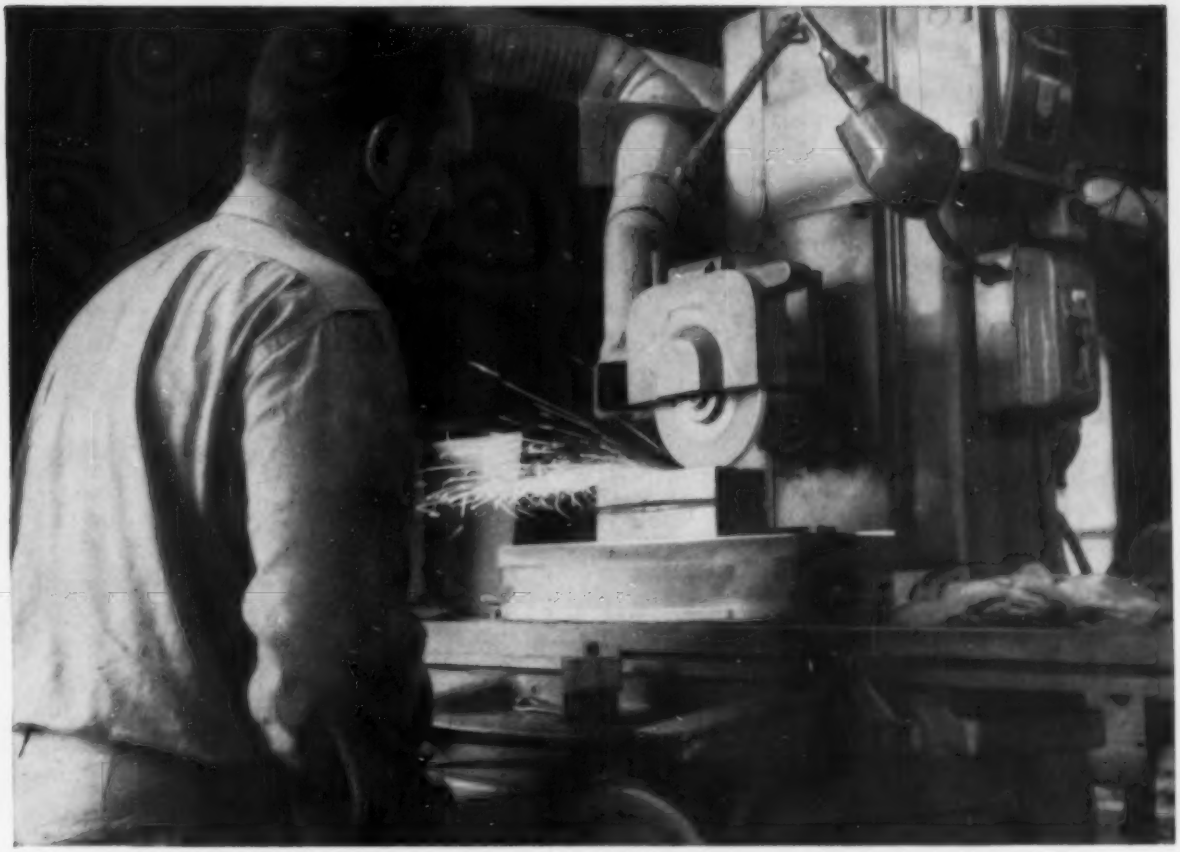

"5 years ago Cities Service solved all our lubrication problems and we've never had another!"

A report from Banner Spring & 4 Slide Co., Van Dyke, Michigan

These Were The Problems 5 Years Ago: Banner Spring & 4 Slide Company, maker of small parts for the automobile, electrical and refrigeration industries, was having trouble. Ways, bearings, and drive shafts on 4 Slide machines were getting insufficient film strength from lubricants and constantly burning out. Likewise, compressors were also running hot, and there was complete puzzlement over what type of lubricant to use for Banner's high-speed sewing machines.

Banner decided to call in a Cities Service Lubrication Engineer. A thorough survey followed, with the man from Cities Service carefully examining each machine and its particular operating conditions.

This completed, he made his recommendations — Trojan H-2 Multi Purpose Grease for the 4 Slide machines, Pacemaker No. 1 Oil for the compressors, and Pacemaker 00 Oil for the high-speed sewing machines.

Banner followed these recommendations to the letter. Result: Not one lubrication problem in the past five years — despite the fact that machinery runs 24 hours a day!

If you're faced with a lubrication problem — or if you're just not sure if your present lubricant is best for the job — talk with the man from Cities Service. Or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

SOME BANNER PRODUCTS: The firm makes all kinds of round wire forms, wire springs, metal clips and flat springs. Use for such products ranges from auto fender support rods to "burlap listings"—the wire frames sewn into burlap which back up automobile upholstery.

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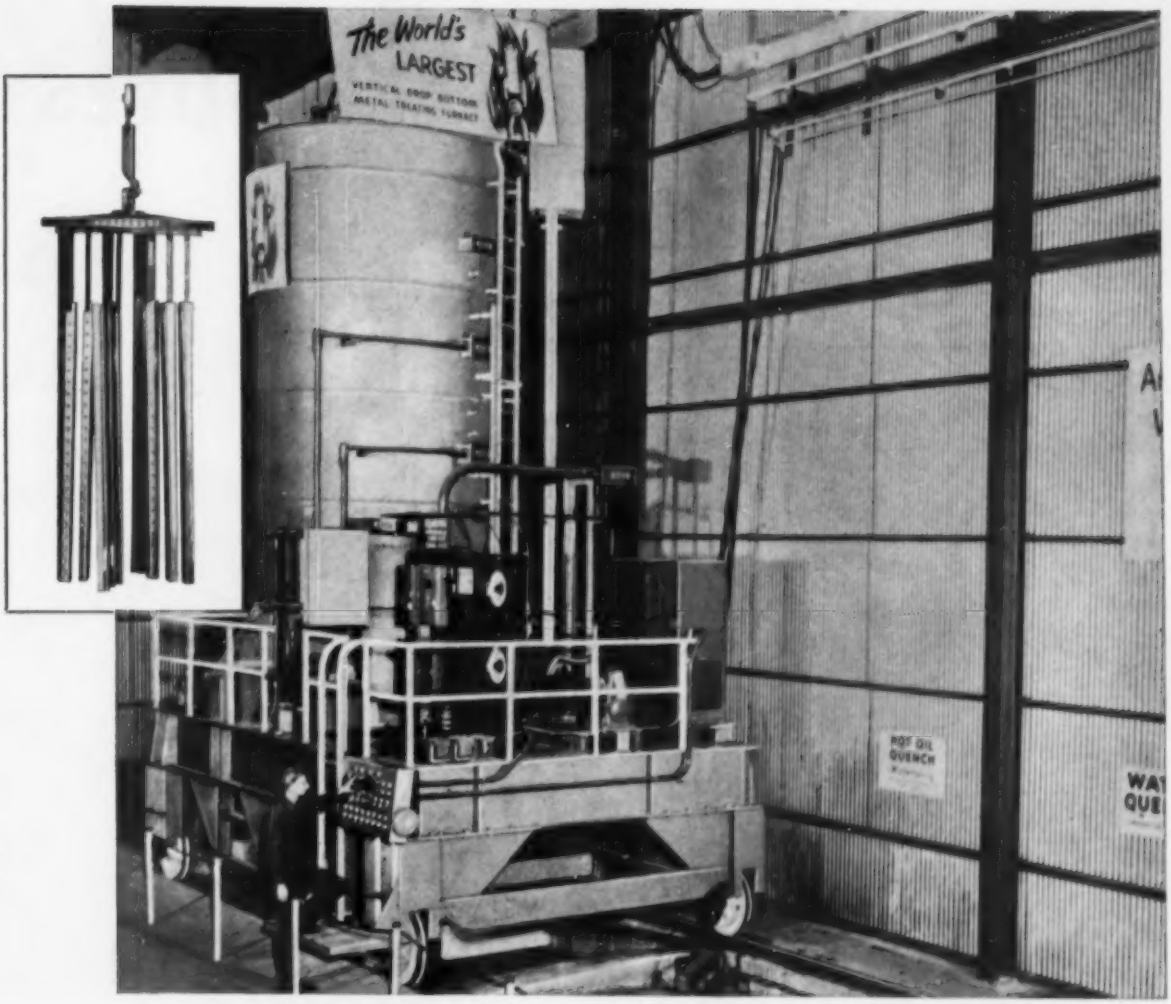

Inconel work-holding fixture is used in this giant drop bottom metal-treating furnace, installed at Metallurgical, Inc., Minneapolis, Minn. Loftus Engineering Corporation designed and fabricated the furnace.

Giant Fixture *for* Giant Furnace...
hot strength of Inconel keeps it warp-free

Look at this Inconel* nickel-chromium alloy workholder (inset).

It's more than seven feet in diameter. Suspends extra long, extra heavy, steel and aluminum parts vertically during heat-treatment. And also during the quench in oil, water, or hot salt.

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What's more, Inconel alloy is readily fabricated, easy to weld. Specify Inconel next time you need a fixture to withstand severe conditions.

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Equipment pictures available — Complete data on the use of Inconel at high temperatures is covered in picture-packed Inco booklet, "Keep Operating Costs Down When Temperatures Go Up." Write for a copy, today.

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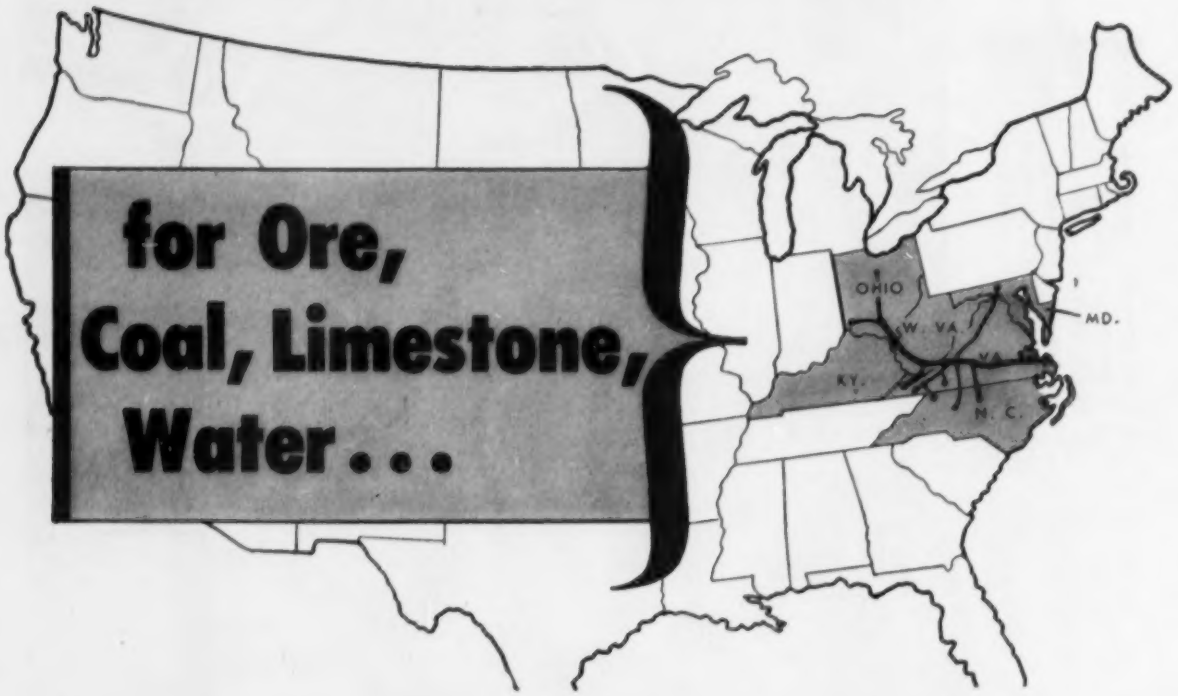

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Ask us for more information about ACP processes for treating aluminum, steel, zinc, brass, copper and other metals, either for protecting the metal or producing a bond for decorative and protective paint finishes.

IMPACT TESTER STRIKES A TELLING BLOW . . . indicates the ability of the painted finish to resist cracking when metal is deformed by a steel ball under a predetermined impact.

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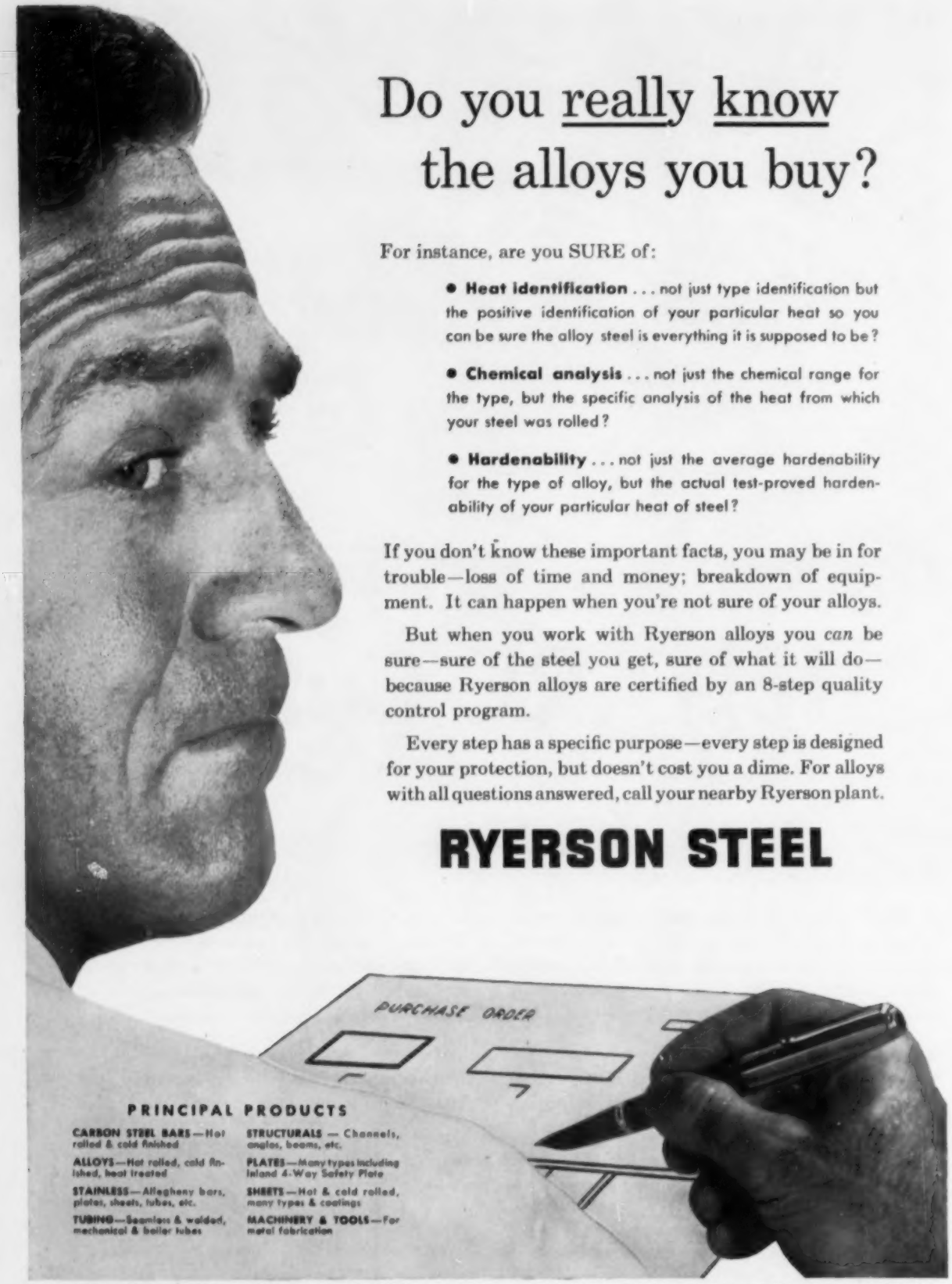
But when you work with Ryerson alloys you *can* be sure—sure of the steel you get, sure of what it will do—because Ryerson alloys are certified by an 8-step quality control program.

Every step has a specific purpose—every step is designed for your protection, but doesn't cost you a dime. For alloys with all questions answered, call your nearby Ryerson plant.

RYERSON STEEL



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Metal Progress
Volume 70, No. 1 July 1956

Failures of Forged End Bells on Large Electric Generators

Forged austenitic steel rings at ends of rotor shafts on two 100,000-kw. generators in Toronto burst from overstressing in the region of ventilation holes. A variety of causes contributed to these brittle fractures in ductile austenitic alloy, such as stress concentration at holes, work hardened metal in the bores, and a variable pattern of residual stress. (S 21, Q 25, AY)

THE YEAR 1954 seems to have been a peculiarly unlucky one for large electrical generators in North America. Bad accidents occurred to two 100,000-kw. machines in Toronto in the first week of April 1954, in addition to the failures of four rotor forgings discussed before the American Society of Mechanical Engineers last winter and summarized in *Metal Progress* in February 1956. The wrecked Canadian units belonged to a set of four generators driven by steam turbines, the oldest of which was put into service late in 1951; they were used for peak loads on the main Hydro-Electric Power Commission of Ontario's network, largely supplied by water power. Results of an exhaustive inquiry into these failures were presented on Feb. 15 by Sir Claude Gibb of C. A. Parsons & Co., Ltd., the manufacturer, in a paper entitled "Report on Investigation Into the Failure of Two 100-MW. Turbo-Generators" to the Institution of Mechanical Engineers* in London, and on Feb. 17 to the Engineering Institute of Canada in Toronto.† What follows is a summary of this paper, with a few sidelights drawn from the discussion.

Failure of Austenitic Rings

Early reports of the accidents ascribed them to explosions of hydrogen gas used for coolant, and since the Bikini "hydrogen bomb" tests were underway at the same time, there was considerable newspaper play on this coincidence. It may be said immediately that hydrogen, either light or heavy, had nothing to do with the generator failures. Rather they were undoubtedly caused by the fracture of one of the two heavy forged rings called "end bells" which confine the return loops

*Reprint, with discussion, from the *Proceedings* of the Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, S. W. 1, London, England, Vol. 169, 1955, No. 29.

†*The Engineering Journal*, 2050 Mansfield St., Montreal, P.Q., Canada, March 1955.

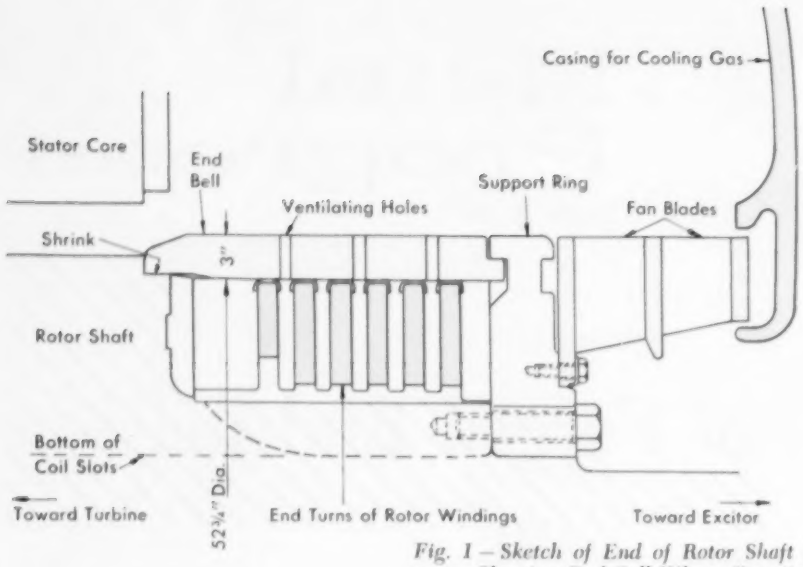


Fig. 1 – Sketch of End of Rotor Shaft in 100,000-Kw. Generator Showing End Bell Whose Function Is to Hold in Place Against Centrifugal Force the End Turns of the Rotor Windings

of the windings at either end of the rotor shaft as shown in the cross section of Fig. 1 and the photograph, Fig. 2.

It is quite desirable that these end bells be made of nonmagnetic materials; a retaining ring of martensitic steel (magnetic) would materially decrease the efficiency of the generator, thus requiring larger windings for a required output. Likewise eddy currents in the magnetic bells would heat them unduly. Consequently much attention has been given to this detail, and several alloys studied. Apparently one austenitic steel has been widely used by British manufacturers, a high-carbon 8-8-4 Ni-Mn-Cr steel of the following approximate composition:

Carbon	0.64 to 0.70%
Silicon	0.37 to 0.45
Manganese	7.23 to 8.18
Sulphur	0.006 to 0.014
Phosphorus	0.020 to 0.032
Chromium	3.80 to 4.09
Nickel	8.40 to 8.83

The bell carries a high "hoop" load when in operation, arising from a combination of stresses which will be discussed later, so it is very desirable that the rather soft and yielding austenitic steel be hardened and strengthened – and this can be done only by cold working (actually, warm working). For such a large ring as this – 52.75 in. inside diameter, 3 in. thick and 21.25 in. long – cold working the ring requires very powerful machinery; in fact, special techniques had to be employed to achieve the required degree of cold working with the 4000-ton press at the forge plant of the steelmakers, Thos. Firth and John Brown, Ltd., of Sheffield.*

"Cold working inevitably produces residual stresses in the finished ring, because improvements in physical properties are a consequence of grain structure distortion. Depending upon the technique of manufacture adopted, the residual stresses resulting from cold working almost certainly will vary considerably from end bell to end bell and from forgemaster to forgemaster.

"This is a feature which neither metallurgist nor designer likes. It has led to investigations into alternative methods of manufacture, including forging on a mandrel under a more powerful press, expanding on tapered mandrels of various sizes and rolling on a special type of tyre mill.

"The method of manufacture adopted depends upon existing facilities, upon the forgemaster's experience and upon his opinions on the quality of the final product. Expanding on tapered mandrels may possibly lead to greater residual stresses than forging under a hydraulic press while on a mandrel. Rolling is a preferred method – always provided the rolls are capable of exerting a load sufficient for the cold work to penetrate through the full thickness of the end bell, since otherwise the inner and outer surfaces would be stretched, placing the center of the thickness in severe tension which would remain as residual stress, the worst possible condition for resisting the hoop stress due to the mass of the bell and the stress produced by the outward

*Text in quotes is verbatim from the original paper.

thrust from inertia of the end turns of the rotor windings.

"To produce end bells of the dimensions required for the Toronto rotors a 4000-ton press was not powerful enough to forge over the full axial length after partial cold working; thus the forging tool was restricted in working to approximately one-third of the length of the end bell by tilting the mandrel.

"The program consists of seven steps:

"1. The ingot is cogged into a billet in a number of reheats, forging being carried out between 2000 and 1650° F.

"2. The billet is cut into blocks under the press.

"3. The blocks are flattened (upset) and the central hole punched and drifted under the press. The shape is trued by flattening and edging.

"4. Hot expanding is carried out on a mandrel in two stages.

"5. The forgings are cooled and then rough machined.

"6. Expanding (by forging under the press on a mandrel) is carried out after heating the ring to 1925° F., then allowing to cool to 900° F. when expanding commences.

"7. Stress-relieving, prior to final machining, by heating for 5 hr. at 750° F. and cooling in the furnace."

By the above manufacturing routine, end bells were produced to meet the specification's minimum tensile requirements, namely, 112,000-psi. yield (0.5% proof stress), 128,000-psi. ultimate, 20% elongation in 2 in., and 30% reduction in area. Acceptance tests for the two Toronto end bells which failed barely made the yield and ultimate, but their ductility figures were well above the required minima. Three tests on one bell, accepted for machine No. 3 which was one that survived, were low in ductility, one registering only 6% elongation!

It might be well right now to say that a large number of tensile test pieces were cut in a tangential direction from the metal in the two rings which failed and from two other surviving Toronto rings which were later fractured in a bursting test to be described. Results are summarized in Table I, wherein E means bell at exciter end; T means bell at turbine end.

Test pieces in this series included those cut from metal as near as possible to the apparent origin of fracture, and from inside, outside and mid-section of the ring. Strengths were fairly uniform throughout the bells which failed – in fact more uniform than in No. 4-E which survived. In all bells, however, the ductility was quite variable and in two thirds of the tests either the elongation or the reduction was less than the specified minimum.

Fig. 2 – Wreckage of Generator Unit Showing Portion of Fractured "End Bell" (Forged Ring) in Center of Photo

"Some significance might have been attached to the results of these tests in relation to the failure of end bell No. 1-E", in the author's words, "except for the fact that much more satisfactory values of elongation and reduction in area were obtained in the tests on the exciter end bell from No. 2 machine (No. 2-E) which also failed in service."

Serious variability in the effect of the strengthening by cold work is evident from the ductility figures and from the fact that many of the test pieces – in fact *all* of the specimens from end bell No. 1-E – broke outside the middle half of the gage length.

In the discussion of this paper in London, V. J. Vickers of the English Electric Co., Ltd., said that a precisely similar failure occurred in 1950 in a test pit when a completed 60,000-kw. rotor was being given its overspeed test. While his associates recognized the harmful effect of the ventilation holes as stress-raisers and had ruled them out of their designs since 1950, they also believed that the considerable differences in amount of cold strengthening by forging introduced large, unknown, but undoubtedly dangerous residual stresses. Consequently his firm started the practice of expanding the ring hydraulically in a rig

Table I – Summary of Tensile Tests on Metal From End Bells

Property	Failed in Service		Burst in Test		Specification
	No. 1-E	No. 2-E	No. 2-T	No. 4-E	
0.5% proof stress					
maximum, psi.	119,000	125,000	123,000	131,000	
minimum	114,000	119,000	116,000	106,000	112,000
Ultimate strength					
maximum, psi.	131,000	140,000	139,000	140,000	
minimum	123,000	133,000	135,000	124,000	128,000
Ratio; maximum	96.4%	89.9%	88.9%	93.5%	
minimum	87.7	89.3	85.5	82.9	
Elongation in 2 in.					
maximum	30.5%	27%	33.5%	31%	
minimum	12	20.5	23	15	20
Reduction of area					
maximum	36%	31%	38%	33.5%	
minimum	21.5	26	28	23.5	30

quite similar to Fig. 3 to produce a hoop stress equivalent to 95% of the lowest value of the yield stress shown in any of the acceptance tests. Some nonuniform permanent set invariably resulted, indicating either a redistribution in stress, or that there were some parts where metal of lower than average strength had yielded. Test pieces cut from such expanded rings showed much more uniformity in mechanical properties. Any distortion too large to be corrected by final machining should be cause for rejection. Furthermore, ultrasonic surveys were made both before and after this final expansion.

The Parsons firm's present practice is also to test hydraulically all nonmagnetic end bells to a mean hoop stress of 78,500 psi., followed with complete radiographic, ultrasonic, and penetrant dye inspection.

As a supplement to this matter of variable stress condition due to cold working, it was also found by machining thin layers from the exciter end bell of Toronto unit No. 3 that the surface layers on the inner bore carried a compressive stress in a circumferential direction of about 22,500 psi., and tensile stresses of about the same magnitude at the outside surface. Other rough-forged bells showed much higher stresses at the surfaces and of quite variable nature – some tension, some compression, in both longitudinal and tangential directions. While much of this bi-axially stressed metal is removed in the final machining, the designer should realize that apparently similar end bells may have residual stresses at the surface of either compression or tension "of a magnitude likely to encroach seriously upon the estimated margin of safety".

Stress-Raisers

Some questions were raised as to the desirability of metal in highly stressed service whose yield, as indicated by the minimum specified 0.5% proof stress, is within 87.5% of the minimum specified ultimate (and which in test actually went as high as 96.4 and 89.8% in spots in the fractured bells and 93.5 and 88.9% in the surviving bells). Whether this was a ruling factor in the failures at Toronto is doubtful, for the fractures, shown in Fig. 4, showed that the bell had broken with brittle failure at a place where it was weakened by three ventilating holes in line.

"From the appearance of the fracture surface of the ring from No. 1 generator, it was deduced that fracture had started at mid-thickness in the ventilation hole nearest to the rotor, that is, the one nearest the tapered end. From that hole the crack had spread in each direction. There was

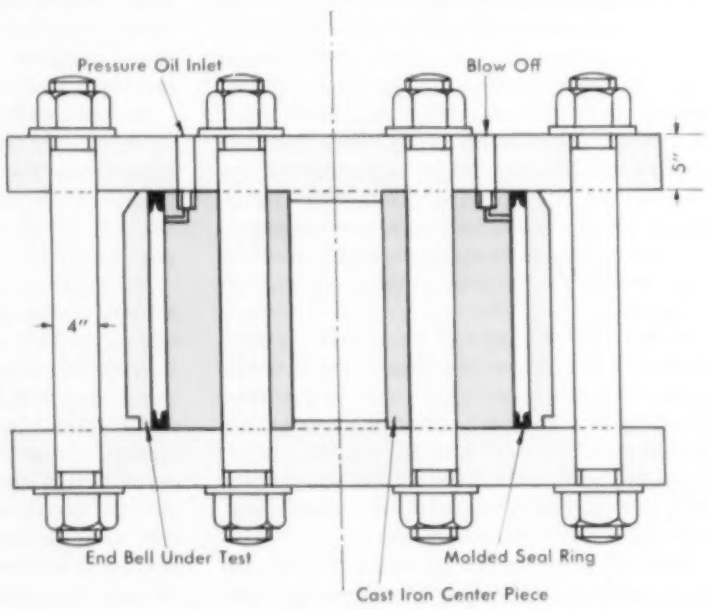


Fig. 3 – Rig for Testing Bells for Bursting or for Fatigue

Fig. 4 – Broken End Bell of Toronto No. 1 Generator As It Was Recovered After the Accident. Below is fracture appearance; section is 3 in. thick by 21.25 in. long; ventilating holes are 1 in. diameter

evidence, too, that when the fracture reached the other two holes it started again in each instance at mid-thickness.

"Examination of No. 2 set after the failure showed that the end bell at the exciter end had fractured in an identical manner.

"There were no flaws or abnormal features which could be regarded as important; the bells had failed in an identical manner, which also seemed to eliminate the possibility of a local fault in the material. The appearance of the surfaces of each fracture indicated that a crack had started near the center at a ventilation hole and was propagated normally to the plane of the principal stress to the tapered edge where the bell is shrunk onto the rotor body. The remaining portion in the opposite direction appeared to have the nature of a shock fracture and to have parted more rapidly."

At the time the accident occurred, engineers in England were studying the failure of some finished rings of this same austenitic material while resting in storage. The cause was determined to be stress-corrosion, sometimes called season cracking. Such cracks can easily be discovered by dye penetrants, and they have, as shown in Fig. 5, a transgranular path in this austenitic steel. The cracks in the Toronto end bells were of an entirely different nature, being intergranular, and no trace of season cracking – nor fretting corrosion at contact surfaces – was found in any of the end bells.

The designers had of course recognized that the round ventilating holes would act as stress-raisers, theoretically tripling at the bore the average stress across the whole cross section, and it was not surprising when three of the surviving end bells from Toronto cracked through the ventilating holes when expanded in the heavy fixture sketched in Fig. 3. However, what might be an even larger effect resulted from the work hardening by the drill. Drilling these austenitic steels is a very difficult operation; carefully sharpened drills were used, and the ends were opened out to a proper radius.

"Several hundred hardness tests were made on the internal surfaces of these holes, using a 10-kg. load with a Vickers diamond pyramid hardness tester. These showed variations from 351 to 657, while the parent metal away from the holes ranged from 280 to 340. Thus, there was considerable work hardening on the surface of the holes which appeared to have no relation to depth of hole – that is, hardening was not progressive with depth, but was a maximum at or about the middle depth of the hole and the hoop stress in the bell is also a maximum at mid-depth. The work hardened skin of the hole was extremely thin and possible explanations are that the drill cuttings or swarf rubbed the surface, sometimes causing surface polishing and at other times causing scratches.

"This situation leads to stress concentrations of a high order. The surface of the holes was too hard and rigid to be relieved by plastic flow. The inability of the metal immediately adjacent to the holes to spread the high stress by deformation is clearly shown by the increasing ductility apparent in the fractured surface (Fig. 4) as the crack proceeds away from the hole. The holes vary in surface finish, but without question the high hardness gives rise to increased notch sensitivity. The fact that, in all the ventilated bells fractured in service or in high-pressure or in cyclic tests, varying numbers of holes other than those through which the fracture took place were

cracked indicates a general, rather than a local, onset of the conditions which immediately precede failure."

While much of the hardened skin on the surfaces of these holes could be removed by "carefully grinding at least 0.04 in. from the bore and subsequently honing to a very fine finish", the bells undoubtedly will be safer if they contain no holes. Despite the circumstance, therefore, that ventilated bells had given completely satisfactory service in many other generators, C. A. Parsons & Co. has decided to eliminate the ventilating holes and to provide a direct-cooling flow of hydrogen to prevent extra thermal stresses in the bells.

Bursting Tests

The first Toronto accident, generator No. 1, occurred after a week-end shutdown and within 20 min. after it had reached speed but was generating only 10,000 kw. Previously it had 567,519 hr. of service, since its installation in October of 1951, had 100 starts from week-end or other shutdowns, and 17 overspeed trip tests. (While these generators were used for peak loads in morning and evening hours, they normally coasted at about 10,000 kw. during the idling hours, except at weekends.) Generator No. 2 had 685,199 hr. of service since its installation in February of 1952, 77 starts from shutdowns, and 17 overspeed trip tests. Its end bell let go on a Monday morning after it had been at full load for about 3 hr. Generators No. 3 and 4 had less service, being installed in November of 1952 and June of 1953.

All the six intact end bells were removed and sent to England for examination. Two major investigations were made on these forged rings; three were used to determine the mode of fracture under steadily increasing hoop stress, two others were used to determine the mode of fracture under cylic stress, and the third to investigate internal stress by Sachs's method.

These bursting tests were made in the heavy rig sketched in Fig. 3 wherein oil could be pumped at high pressure into the annular space between the end bell under test and the cast iron center piece. The ventilation holes were blanked off with inner and outer washers, and suitable strain gages attached. Results on three intact bells from Toronto, one undrilled replacement, and four smaller (37-in.) bells are shown in Table II.

All the bells noted in Table II which cracked failed quietly without the crack spreading, except Toronto No. 4, exciter end, which failed with such explosive force as to damage the test equipment and with a fracture almost identical to Fig. 4. No less than 24 holes in the Toronto 1-E and 68 in Toronto 2-E (which had failed in service) showed minute surface cracks. None of the ventilated bells tested as above had such cracks *before* testing, but 2-T had 12, 3-T had 9, and 4-E had 26 holes showing tiny cracks *after* testing. The microscope showed that these cracks were invariably intergranular.

This indicates, therefore, that despite the stress-raising action of the holes, the 8-8-4 Ni-Mn-Cr steel rings, cold worked and fabricated as described, will stand nearly 80,000-psi. mean hoop stress without exterior evidence of failure, and this stress is about 70% of the minimum yield and 65% of the minimum ultimate. How does this compare with the estimated working stress?

"The hoop stress applied in service during normal running conditions to the Toronto end

Fig. 5 Micrograph Showing Typical Transgranular Stress-Corrosion (Season Cracks) in 8-8-4 Ni-Mn-Cr Nonmagnetic Steel

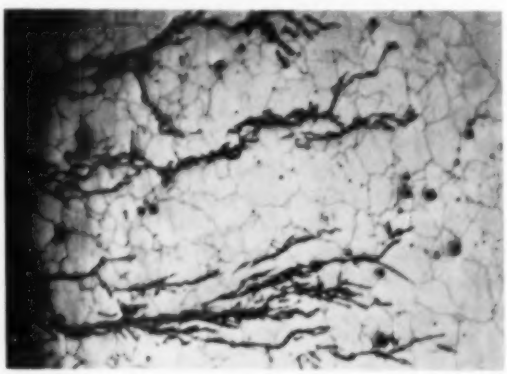
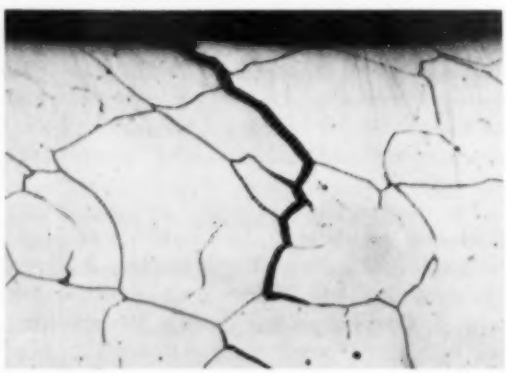


Fig. 6 Intergranular Cracks Found in End Bell From Toronto Generator No. 1 After Failure in Service



bells was 43,000 psi. from centrifugal loading of the copper coils within and from its own mass. At the nose of the bell where it is shrunk to the rotor body, the total stress is 58,000 psi. when both rotor and bell are cold, but is appreciably less under normal operating temperatures, when body and bell are warm, because of the greater expansion coefficient of the austenitic bell material. As described below, the stress at this shrunk end could be increased were the rotor body to be hot after coming off a high load and the end bell appreciably cooler."

Table II — Bursting Tests on End Bells

Bell	Mean Hoop Stress	Result
Toronto No. 2-T	80,000 psi.	Cracked through two holes
Toronto No. 3-T	88,000	Cracked at one hole
Toronto No. 4-E	94,700	Fractured completely through three holes
Toronto replacement, undrilled	97,400	Expanded without cracking
37-in. drilled bell, used	96,200	Cracked at one hole
37-in. drilled bell, new	91,200	Cracked at one hole
37-in. undrilled bell, new	111,500	Expanded without cracking
37-in. undrilled bell, new	111,000	Expanded without cracking

Obviously the stress due to shrink is greater than the stress due to inertia at normal speed and is about 72.5% of the minimum bursting load in the above tests, and little more than 50% of the specified minimum yield. However, an appendix which calculates the accumulated stresses due to (*a*) shrink, (*b*) hoop stress and (*c*) axial bending in an end bell acting elastically under various temperature conditions shows that the highest total tensile stress appears to be 2.5 in. from the shrink joint and is about 78,500 psi. when the end bell is 35° F. cooler than the rotor and its windings, as is expected sometime after reaching normal running speed. This appears to be perilously close to the minimum bursting strength of the ventilated end bells which were tested to destruction. Furthermore the extra stress at the shrink after the machine has been shut down and the end bell cooled about 40° F. below the still-warm rotor will induce a total hoop stress at the shrink of about 72,500 psi., which is considerably above the 62,000 psi. which started fatigue failure in surviving bells in a relatively few cycles, as will now be shown.

Fatigue Tests

There remains the question as to whether the fluctuations in loads set up by the numerous shutdowns and overspeed trials would induce fatigue failure at unexpectedly low stresses. This was investigated in the fixture shown in Fig. 3, wherein the interior pressure was varied cyclically within chosen limits.

The surviving bell from the turbine end of Toronto generator No. 1 failed after 76 cycles of stress from zero to 62,000 psi. mean hoop stress, fracturing beginning at the hole in a row of three similarly placed to the ones involved in the Toronto failures (and to Toronto No. 4-E in the bursting test).

Next, the surviving bell from the turbine end of generator No. 4 was tested in a series of increasing steps: 500 cycles at 41,500 psi. mean hoop stress, 500 cycles at 53,000 psi., and 464 cycles at 62,000 psi., whereupon it cracked at a hole near the shrink end. No cracks could be found in any hole prior to the last run.

Finally an undrilled replacement withstood 924 cycles at 67,000 psi. without damage.

"The cracks produced in these cyclic tests were similar to those produced in the single loading pressure tests. There was no deformation of the material near the holes, but as the cracks extended away from the holes the material deformed in front of them. It seems clear that the failures were produced because cracks can be started at the surface of the holes under repeated applications of a lower stress than that required to start them in one application."

Rotating-beam fatigue test specimens, cut from the Toronto bells, showed that the endurance limit of the austenitic steel was ±47,000 psi. This is rather low, being about 35% of the ultimate tensile strength, whereas it should be nearer 46% in martensitic steels. The stress conditions in this test (from 47,000 tension to 47,000 compression) were so different from service stressing (from zero to 62,500 psi. tension) that a Haigh machine was used for fluctuating axial loads. At the quoted service loadings the test pieces broke at 1,600,000 cycles. Thus the actual performance of the steel was "very far below that which would be expected from fatigue testing".

The Brittle Fracture

"The Toronto failures had a close resemblance to the 'brittle fractures' that have occurred in welded ships, high-pressure gas mains, fluid storage reservoirs and other structures, character-

ized by high general stress and the presence of a surface crack or a constructional feature which introduced a concentration of stress – especially if aided by a localized deficiency of ductility that may start a local or restricted crack, which, entering the region under general stress, sets off therein an extensive crack of great suddenness and probably with catastrophic consequences.

"These conditions of high general stress, presence of a stress concentration and local deficiency in ductility are those which apply to the end bells. The failures would thus begin at points of stress concentration which might be cracks formed at the surface of holes, and the cracks propagate rapidly. Furthermore, the surface of these fractures showed chevron-like markings which enabled the point at which the failure began to be identified.

"The only respect in which the failures in the end bells differed from the characteristic mild steel brittle fractures was that they were intercrystalline and not transcrystalline or cleavage. This may be because the end bells were of austenitic steel in which fracture normally is intercrystalline*, whereas in mild steel fracture is normally transcrystalline.

"A large number of investigations have been carried out on brittle fracture to ascertain the conditions under which it occurs and many factors have been suggested as contributing to it. Of these, the main ones seem to be the presence of a multi-axial stress system (insofar as the stress system may limit ductility and thereby promote cracking), a notch of some kind, a low temperature and low notch toughness in the steel. These factors apply particularly where a brittle crack is initiated. After initiation, a brittle crack may spread extensively where the general stress system may be only simple tension – for example, the circumferential tension at the shell of a cylindrical storage reservoir – the spreading crack itself carrying with it as it travels its own stress concentration feature and system of complex stresses.

"Various combinations of these factors may cause brittle fracture. For example, if the notch is very sharp and the temperature very low, it may not be necessary for the steel to have a low impact toughness to fail. Whereas if the notch is sharp and the steel has a low impact toughness, it may not be necessary for the temperature to be low for failure.

"It is clear that in addition to the fact that the fractures of the end bells had most of the characteristics of brittle fractures, the conditions of service conformed with the circumstances under which brittle fracture may occur. The hoop stress, shrink stress, thermal stress, and residual stress could, in combination, give a resultant stress high enough to support the propagation of a brittle fracture in a susceptible material if initiated by a feature of sufficient intensity. This is the significant and important fact of a brittle fracture because usually working and design stresses *exceed* those able to support propagation. The nonmagnetic steel has a relatively low impact toughness. At times the temperature of the bells was low and the holes and small cracks formed in them by repeated cycles of stress would provide the notches required to start brittle fracture."

Conclusion

In conclusion it might be stated that the advantages of austenitic over martensitic alloys are real to the performance of large generators. The more-or-less standard 8-8-4 Ni-Mn-Cr alloy can only be hardened by warm working. Alternative nonmagnetic alloys capable of being quench hardened are too susceptible to season cracking for utilization. Grain-boundary precipitates during fabrication operations can be minimized by rapid cooling through the temperature range favorable to their nucleation and growth. Cold expansion of the rough machined end bell will iron out many variations in internal strength and residual stress; carefully controlled machining operations on the final finishing cuts will minimize sizable stress concentrations of unpredictable nature at the interior and exterior surfaces. Since about one half the working stress arises from its own mass, increasing the thickness of the end bell (and consequently also its radius of gyration) only slowly reduces the working stresses.

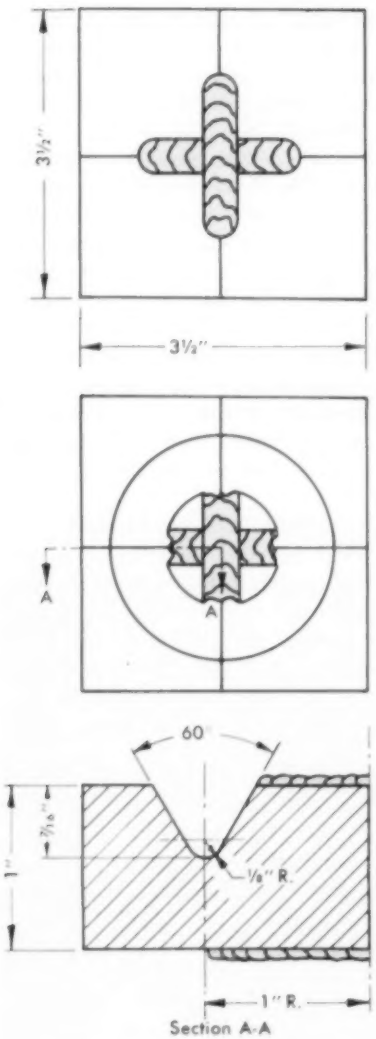
The conclusion is that the most obvious source of weakness, the ventilation holes, must be eliminated, and the thermal stresses controlled by revised techniques of hydrogen cooling, so that the operating temperatures are not only low (to protect the insulation and the conductors) but also uniform (to avoid large thermal stresses in the end bell).

*In the discussion in England, Charles Sykes, chief of the Brown-Firth Research Laboratories, said that some carbides precipitated at the grain boundaries in the austenitic steel, and that deficiencies in ductility and low Izod impact values could be correlated with larger amounts of grain-boundary precipitate. It occurs to the Editor that this precipitate might also favor an intercrystalline fracture.

Selection of Stainless Steel Electrodes for Trouble-Free Welds

*By R. DAVID THOMAS, JR.**

Welding cracks in Type 347 can be eliminated by using an electrode which will produce a weld containing a small amount of ferrite. Such welds require heat treatment to prevent embrittlement in service. (K I, SS)



Circular Groove Test Specimen

THE CHROMIUM-NICKEL stainless steels are readily weldable and for many years the only major problem associated with stainless weldments was localized intergranular corrosion in a zone parallel to the weld bead. Such corrosion is the result of precipitation of carbides at grain boundaries and can be avoided by using an alloy like Type 347 which contains about 1% columbium to stabilize the carbon. Unfortunately, in recent years when Type 347 weldments have been required in heavy sections or for long-time, high-temperature service, or for low-temperature service where high impact strength is necessary, some new problems have arisen both during welding and in service, associated with cracking and embrittlement of the weld metal.

For many years we in the welding industry have recognized that sound weld metal can be guaranteed if we load the composition with ferrite-producing elements, like chromium, silicon and columbium, and keep the austenite-forming elements, like carbon, nickel and manganese, to a minimum. A two-phase microstructure with 4 to 10% ferrite in a matrix of austenite has long been considered ideal for weld filler metals of the 347 type. Welds containing no ferrite, frequently called "balanced composition" welds, will invariably show a marked tendency to hot tears, either as gross cracks or fine microfissures, and often have little or no tensile ductility.

Unfortunately, the secondary ferrite phase is not desirable for long-time service at high temperatures. It is high in chromium and silicon and low in nickel so that it

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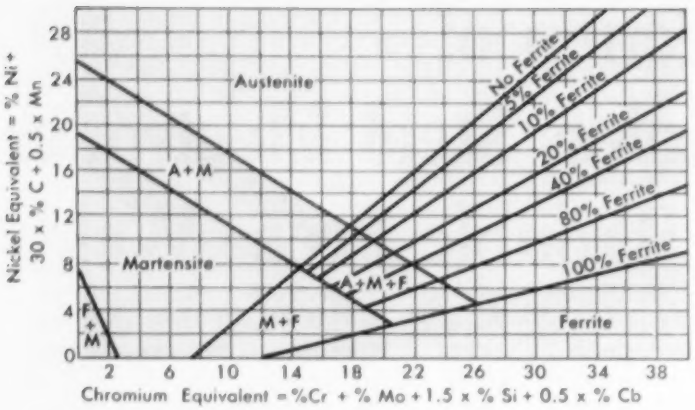


The Schaeffler Diagram Used to Compute the Amount of Ferrite Present in Stainless Weld Metal

may transform to the sigma phase at certain elevated temperatures. This transformation causes a loss in notch-impact ductility and also, in some instances, a loss in corrosion resistance.

Imagine, now, the metallurgist who is called upon to specify the filler metal for use in welding the high-temperature steam piping for a new stationary power generator for operation at 1100°F. For such service the wall thickness might well be 1½ to 2½ in. so that the thermal stresses during welding are enormous. Cracks in the weld metal cannot be tolerated so a welding rod that will produce a weld metal with at least 4% ferrite should be used. Such a weld metal, however, will in time become embrittled in service.

No one is sure why ferrite in an austenite weld metal structure is so effective in overcoming cracks and fissures. A number of theories and explanations have been suggested and most have this in common: Cracking is caused by interstitial residuals. I like to visualize that when the molten metal is solidifying, it sends out a "tree" of ferrite which somehow collects and distributes in small increments these undesirable residuals within the core of the advancing dendrite. In the absence of the ferrite – that is, when austenite is formed directly from the molten weld – the residuals are gradually accumulated and pushed ahead of the advancing dendrite and collect in the grain boundary. Shrinkage stresses cause these weakened areas to pull apart into fine cracks or fissures.

We are accustomed to thinking of the austenitic stainless steels as single-phase equiaxed grains of austenite because that is what we almost invariably see when we examine wrought plates, sheets or bars. We forget that the original ingot was two-phased with a little ferrite in a matrix of austenite. Under equilibrium conditions, all of the ferrite would have transformed to austenite but the ingot cooled so rapidly that "cores" of dendrites remained as ferrite. Hot rolling or forging the ingot facilitates the homogenization of the structure, causing all of the ferrite to be absorbed by the austenite.

Welding almost invariably results in a quench even more severe than that occurring in an ingot when it freezes. Hence, it is customary to find in stainless steel a dendritic cored structure with ferrite islands surrounded by austenite. The amount of ferrite in the structure can be computed from its chemical composition by using the time-tested Schaeffler diagram. In such a computation the composition of the metals being welded must be considered, since they contribute a third, and sometimes, as when using the submerged-arc process, half of the metal in the weld bead.

Most Type 347 pipe is produced with chromium on the low side and nickel on the high side of the specified range. Consequently, a filler metal which undiluted would give 5% ferrite may have no ferrite when diluted with a base metal rich in austenite-forming elements. This is one of the reasons that cracking occurs most frequently in root pass welds.

This ferrite which is so beneficial in eliminating cracks during welding presents a serious problem in service at temperatures at which it can transform to the brittle sigma phase. The resultant embrittlement could cause a failure in the steam line, a catastrophe in which a man's life might be at stake.

Time is an important factor in the formation of sigma. The ferrite usually transforms slowly to sigma but occasionally Type 347 vessels will become embrittled during the relatively short heat treatment cycles if the ferrite content is

Typical Two-Phase Structure of Stainless Steel Welds. Etched in aqua regia glycerol; 500 ×. 7% ferrite

over 10%. The embrittlement due to sigma formation can be substantially reduced by a spheroidizing or solution anneal. The answer to the sigma embrittlement problem is to refrain from using an excessive amount of ferrite and to specify that it be spheroidized by a high-temperature anneal before the weldment is put in service. Such a technique is now the only practicable solution, but current development programs indicate that better methods are possible.

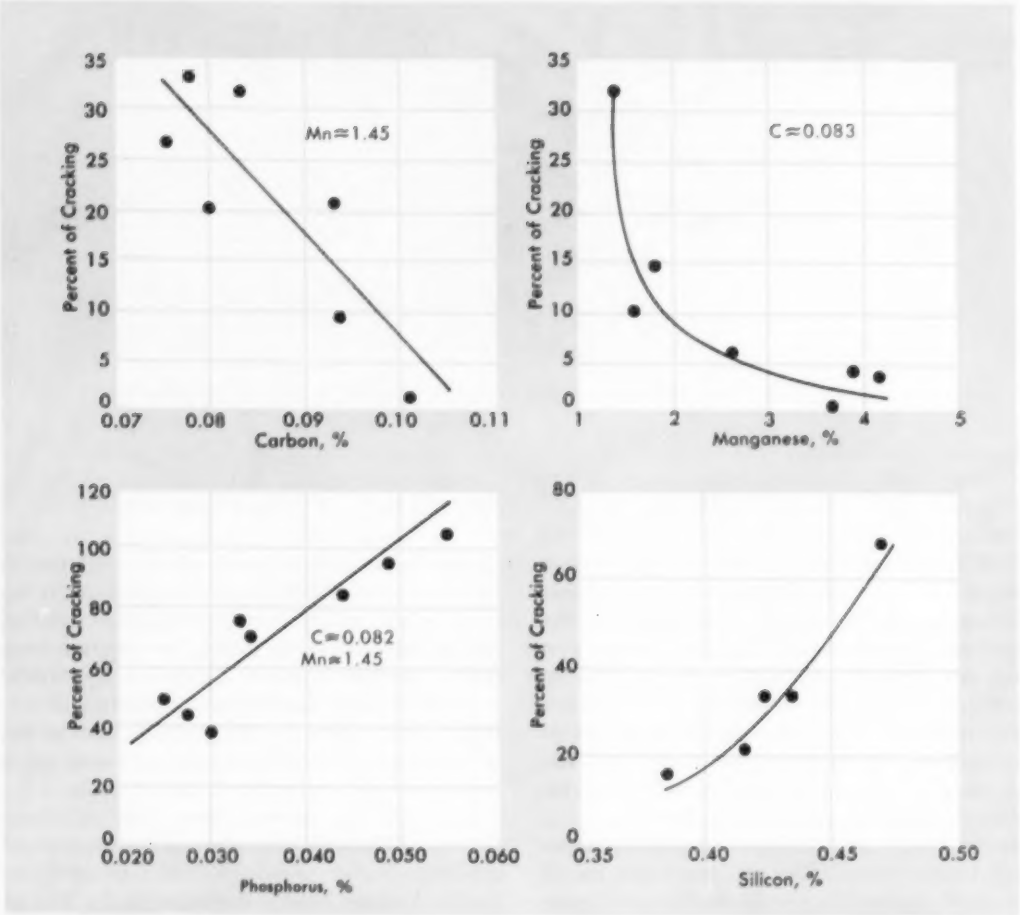
In the course of a development program sponsored by the Atomic Energy Commission on all aspects of this welding problem, the prevalence of cracking in fully austenitic welds was found to be greatly influenced by certain elements in the composition of the weld metal. The detailed results obtained so far under this program have been published elsewhere. The following remarks summarize some of our findings relating to cracking in fully austenitic compositions and to the selection of stabilized stainless weld metals for various service applications.*

Amount of Cracking in Circular Groove Test Is a Function of Weld Metal Composition

We used a circular-groove test specimen (see p. 73), which in most instances caused cracking if the microstructure contained no ferrite. A single bead is deposited in the root of the circular groove in the test piece and after cooling is examined visually for cracks. In such a test we were free to vary both the filler metal and the base metal and were amazed that the pattern of results we obtained was so beautifully consistent.

The complete data are being analyzed by an electronic computor but the effects of the important variables are illustrated in the graphs on the next page. In all instances chromium and nickel were about 19 and 13% respectively. Nickel was maintained at the high level to avoid the possibility that any variable might cause the formation of ferrite and thereby suppress any cracking. The results indicate that cracking can

*The entire program is under the technical guidance of a committee headed by V. N. Krivobok and including F. W. Davis, M. A. Scheil, W. O. Binder, R. B. Gunia and W. B. DeLong. The cracking tests were supervised by L. K. Poole and more recently by T. J. Moore. The continuing program is under the general survey of H. C. Campbell, who was recently added to the Advisory Committee.



Effect of Carbon, Manganese, Phosphorus and Silicon Contents on Weld Metal Cracking

be eliminated by making the composition high in manganese, low in phosphorus and silicon, and with as much carbon as possible. Such a ferrite-free weld has adequate stability without the need for a spheroidizing anneal.

Recommendations

It is beginning to appear that the solution to welding Type 347 is not to use Type 347 steels. Each month more and more applications call for the use of Type 304 L instead of 347. One of the big advantages of the columbium-free alloys is that they do not become embrittled even when they contain a normal amount of ferrite.

For the welding of Type 347 steels for service from room temperature up to 800° F., the standard grades of Type 347 electrodes, which produce a weld metal containing 4 to 10% ferrite, are quite acceptable. For the very best properties a solution treatment at 1950° F. is recommended, but for most vessels, the expense and difficulties of such a treatment make it impractical. Even so, the as-welded properties of the joints are adequate for most types of service.

For elevated-temperature service, conventional 347 filler metals should prove satisfactory, providing a restricted range of ferrite (2 to 5%) is specified. A solution anneal is mandatory for long-time service at elevated temperature. If a solution anneal is not feasible, some consideration might well be given to the new high-manganese type of fully austenitic weld metals.

For pressure vessels for very low-temperature applications, 347 welds should be solution annealed if 15-ft-lb. Charpy notch impact values are to be consistently obtained. A better answer is to select Type 304 L base metal and Type 308 L weld metal.

Use of Tap Water in Magnetic Particle Inspection

*By J. L. McCABE and B. HIRST**

Tap water with suitable rust inhibitors and wetting and antifoaming agents may be substituted for the petroleum distillate now used as a medium in magnetic particle inspection systems. (S 13)

THE PETROLEUM distillate which has been used as the carrier in magnetic particle inspection systems for about 20 years has many disadvantages. It is a fire hazard and many fires have been started in automatic inspection machines when electric sparks at worn contacts have ignited the bath. Occasionally the distillate has been responsible for skin reactions among operators who were allergic to it. Other disadvantages include its comparatively high cost, difficulty in removing it after inspection and the possibility that parts will rust after its removal.

Water has often been tried in the past as a substitute medium but was never satisfactory because of rusting, inability to wet the parts completely and difficulties in securing the proper dispersion of iron oxide pastes in the bath. These problems can be overcome by using water-soluble rust inhibitors and suitable wetting and antifoaming agents, so we can now use clean tap water with the proper additives as a carrier for both the visible and fluorescent particles used in magnetic inspection.

In preliminary tests conducted on a standard ANQ machine, we used a great variety of test parts to determine the minimum amount of additives required to give a sensitivity equivalent to that obtained with the petroleum distillate medium. The most satisfactory compositions are shown in the table. Results of the initial tests were so encouraging that the Air Force approved a temporary deviation from MIL-I-6868 to permit us to continue the investigation with production parts and production inspection equipment. The equipment included an automatic machine used to inspect compressor blades in assembled rotors, a Type ANQ machine used for inspection of small parts and a Type MAV automatic machine used for inspection of compressor blades.

*Evendale Operating Dept. Laboratory, Aircraft Gas Turbine Div., General Electric Co., Evendale, Ohio.

Compositions Used for Magnetic Particle Inspection

TYPE	PASTE*	VEHICLE BASE	TAP WATER
Oil suspension, visible paste	1.5 oz. No. 9B Red	1 gal. petroleum distillate†	—
Fluorescent paste	1 oz. No. 10	10 gal. petroleum distillate†	—
Water suspension, visible paste	2.5 oz. No. 29 Red	37 oz. water vehicle‡	5 gal.
Fluorescent paste	1.0 oz. No. 12	37 oz. water vehicle‡	5 gal.

*Magnaflux Corp. designation.

†Properties of petroleum distillate are: kinetic viscosity at 100° F., 3 centistokes max.; flash point, closed cup, 135° F. min.; initial boiling, 390° F. min.; final boiling, 500° F. min.

‡Composition is 0.3% antifoam agent, 3.9% rust inhibitor, 12.8% wetting agent, 83.0% tap water.

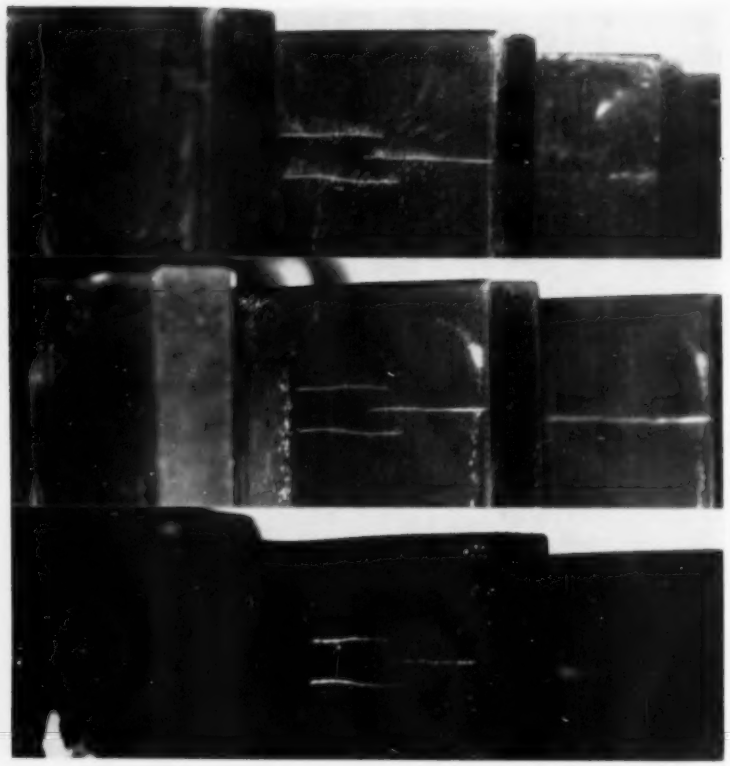


Fig. 1 – Grinding Cracks on Involutes of Gear Teeth. Top – Oil suspendible magnetic particle method. Center – New water-suspendible visible magnetic particle method. Bottom – New water-suspendible fluorescent magnetic particle method

Complete records of all production parts tested were made as well as pertinent information concerning the stability and performance of the baths. Frequent tests were made on paste concentration, "sensitivity" of the method and wetting ability of the baths.

The sensitivity of the water-base magnetic particle inspection methods was tested in the following manner:

1. Selected parts such as gears, blades and bolts with known defects were inspected by the standard visual method, by the visual method using a water vehicle and by the fluorescent magnetic particle system employing water. Sensitivities were found to be equivalent in all methods, as shown in Fig. 1 and 2.

2. Large production lots of small parts which had been found acceptable by the new method were rechecked by the standard method. The inspections were performed by two separate groups of certified inspectors. The results of this comparison were identical.

3. Parts with known defects were introduced into production lots and were successfully segregated by operators using the water-suspendible fluorescent magnetic particle method. These operators were unaware that the defective parts were deliberately included.

Before testing, it is essential that all oil, grease or other foreign matter be thoroughly removed by vapor degreasing. Vapor degreasing was not feasible for cleaning the assembled rotor because of its size. A pressure spray wash solution consisting of the vehicle base combined with tap water in a 1:10 ratio and used at a temperature of 160 to 180° F. was found to be satisfactory for these assemblies. Adequate cleaning is indicated by complete wetting of the part in the magnetic particle solution.

The components can be inspected by either wet continuous or residual techniques. There is no change in the current or number of magnetizing charges from that used in oil-suspendible solutions. With visible paste there is no need for any special facilities for examination. Fluorescent paste inspection must be conducted under a black light in a darkened booth.

After inspection the parts are washed in a 1:10 solution of the vehicle base in tap water at 160 to 180° F.

Prior to charging a machine with water-suspendible paste all parts of the unit must be thor-

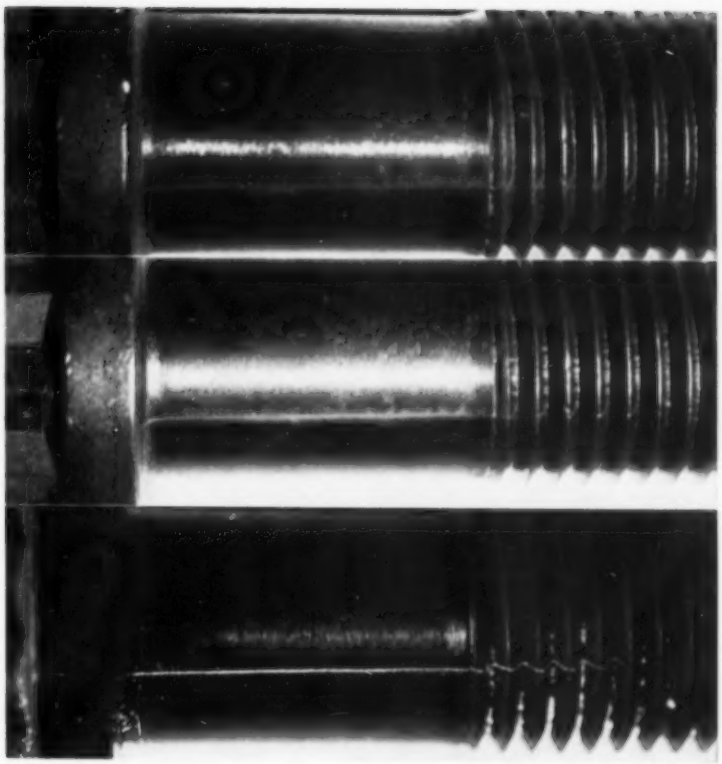


Fig. 2 – Seam in Shank of Bolt. Top – Oil-suspendible magnetic particle method. Center – New water-suspendible visible magnetic particle method. Bottom – New water-suspendible fluorescent magnetic particle method

oughly cleansed of old paste and of petroleum distillate since the two systems are incompatible. Traces of the oil-suspendible systems can make the detection of flaws highly problematic. During operation the system should be frequently checked for the wetting ability of the suspension by flowing the solution over a test specimen. If the solution does not cover the specimen thoroughly and tends to run back from the edges, an additional amount of vehicle base should be added until complete wetting is obtained. Concentration of particles is determined by filling the usual 100-ml. centrifuge tube and allowing it to stand for a half hour. At the end of this period the precipitation in the tube for the fluorescent paste should not be less than 0.1 nor more than 0.3 ml., and for the visible paste not less than 1.7 nor more than 2.5 ml.

During use some evaporation takes place and it is necessary to add tap water for make-up. It is convenient to reference-mark the solution level in the machine to determine when additional water is needed.

When a final 1:10 wash of vehicle base and tap water at 160 to 180° F. is used and allowed to dry on parts that have been inspected, rust is inhibited sufficiently for transient storage. Test pieces after such preparation have been exposed to the atmosphere for periods up to one month. Others have been subjected to 100% relative humidity at 100° F. for similar periods. Parts kept in finished stores for 30 days with no other protection have been regularly examined. In none of these instances was there any evidence of rust. For extended storage, specially compounded rust inhibitors are used. Resistance of the part to fingerprint corrosion after this wash has not been fully evaluated.

The water-base systems are at least as sensitive as those using petroleum distillate and cost much less. In addition they have eliminated or reduced the fire and health hazards associated with the petroleum distillate. The rust-inhibiting properties of the new mediums are effective, at least for short-time protection.

Potential users of the new water-suspendible inspection systems must obtain approval from Wright Air Development Center when Air Force contracts are involved. It is expected that new Federal specifications will eventually be issued to permit the use of the water-base mediums as alternate methods of inspection.

Frontiers of Atomic Science*

Let us consider one area of modern science and mathematics having to do with molecules, atoms and subatomic particles. Remember, no one has ever seen a molecule. Let us start around the turn of the century when investigations in thermodynamics and mathematics showed us how to predict the course and extent of chemical reactions. With the aid of these new tools, man began to juggle molecules large and small and make plastics, synthesize alcohol and crack petroleum.

By that time man had learned that atoms were not indivisible particles but that their central cores were very minute and contained most of the mass, and that the shell was mostly empty space with a certain number of light electrons. Later was the amazing discovery that the faster an electron moved, the heavier it became!

Mathematical relationships between wave lengths and energy of radiation emitted from "excited" atoms led to the first really fundamental discovery in the structure of the atom. Experimental and mathematical investigations continued on what were called "stripped" atoms – that is to say, neutral atoms from which one or more layers of orbital electrons have been removed. Man had begun to attack the nucleus itself.

While Rutherford's experiments during World War I failed to "split the atom", he quickly established the basic mathematical laws governing radioactive decay and formation. In 1932 Chadwick discovered the neutron – a chargeless atomic particle with about the same mass as a hydrogen atom. In relatively quick succession came the discovery that the nuclei of various elements could capture neutrons and produce radioactive materials, culminating in the experiment wherein uranium was fissioned by capturing a neutron and with the release of a perfectly enormous amount of energy.

In 1906, Einstein (a theorist rather than an experimentalist) had published his equation showing how much energy could be released by converting matter into energy. Nevertheless extremely accurate quantitative measurements made a few years later showed that if there were such a gain or loss, it could not exceed the experimental error of one part in one hundred million – a statement which is still true, but it does not apply to the reactions of the *nucleus* of the atom. (Einstein's equation explains the release of energy during fission of a heavy element, and during radioactive decay.)

The search for smaller and smaller particles continues. Subnuclear particles such as mesons, antiprotons, neutrinos, some discovered several years ago, and some only recently, fascinate us. The neutrino, in particular, is an interesting application of mathematics. It is an imaginary particle – not as yet isolated – conceived to explain away certain observed effects in radioactivity wherein electrons (beta particles) are emitted in a way which violates the laws of conservation of momentum. In effect, if we add 3 and 3 in our experiments and find that the sum always equals 5, we then invent a neutrino to bring the total up to 6. This most elusive particle is the object of a very intensive manhunt within the recesses of one of our very large reactors.

Perhaps the very frontier of science is now concerned with the composition of the "atomic glue", that mysterious force which binds together the atom. The positive charges on the particles comprising the nucleus repel each other; consequently there must be terrific disruptive forces.

Atomic glue, therefore, must possess some extremely interesting properties; although it must have no net charge in itself, it is able in some manner to neutralize these tremendously powerful repulsive forces and stabilize the nucleus. If we could weaken this glue we could obtain *enormous* energies from the disintegration of the atom, energies far, far in excess of what we can presently conceive. Perhaps this can be done on the atom smashers of extremely high voltage now under construction.

What do we hope to find as a result of learning more and more about less and less? We don't really know. But once more, we have every right to predict that we may be on the verge of a totally new discovery.

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*Verbatim extracts from "More and More – About Less and Less", address at Phillips Andover Academy by George G. Manov, technical assistant to Commissioner Willard F. Libby, U.S. Atomic Energy Commission.

Metallurgists Needed Badly!

It is suggested that this insert be taken out and given to some bright boy who has just graduated or who is still in high school

VISUALIZE the world without metal and what strange, primitive conditions you would see! No tall buildings, no plumbing, no electricity, no automobiles, no stoves, no refrigerators. Even simple frying pans and ordinary table knives would be unknown. We would be back in the Stone Age!

Most of the devices that make our lives easier, more convenient, more comfortable, are possible only because Nature has endowed us with no less than 65 different metals, and one of the chief reasons why metals can perform so many different tasks lies in the fact that each metal has different characteristics – hence, different uses. Then, too, combinations of metals increase the variety of possibilities to an infinite number.

Pure iron, for example, is relatively soft and weak. Thus, no automobile manufacturer would ever use it for a gear or an axle because it would wear out quickly and not be strong enough. Instead he selects steel, which is iron mixed with small quantities of carbon plus other metals such as manganese, nickel, chromium or molybdenum. After machining to correct size, such steels can be hardened by heat treatment; they are then strong and wear resistant and will endure for a long time. Copper, on the other hand, has low resistance to electrical currents; consequently it will be first choice for electrical wiring. Airplane manufacturers prefer aluminum for fuselage bodies and fittings because of the light weight. Certain heavy metals such as radium and uranium are unstable and hence radioactive; the radioactivity can be used in medicine for curing disease or for peacetime creation of electric power; the instability is the basis of the atomic bomb.

Today, industry tailors metals to fit each specific need. This wasn't always true. While men have used a few metals for a long time as weapons, cooking utensils, and ornamentation, for thousands of years they found these materials only as simple metals on the earth's surface. They could use them for just a few of their needs. After the discovery of metallic ores it undoubtedly took centuries of experiment to discover ways of reducing these ores to metal and good methods of refining them of impurities. Today, however, metallurgists have not only mastered the purification of metals, but have learned to combine them into alloys most useful for our varied requirements.

What is a Metallurgist?

The need to determine which metal suits a job or how to combine metals to achieve certain results has created a new science known as "metallurgy," and a new set of engineers known as "metallurgists" or "metallurgical engineers." To take the guesswork out of metal manufacturing, industry employs these experts.

They have a wide variety of jobs and titles. Their common characteristic is that they have supervision over some work on metals, study the processes or inspect the products, sell metals or furnaces or supplies needed in their fabrication. These men we will call metallurgists. Today the metal industries of the United States employ at least 50,000 of them. (No less than 26,000 are members of a single engineering organization, the American Society for Metals.) To maintain the numbers of this group of 50,000 men vitally needed in industry there are only 650 young men graduating with metallurgical training from the 53 American colleges which offer such courses. The supply is nowhere near the demand. Obviously there is good pay and many opportunities for such graduates.

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Extractive Metallurgy – Metallurgical engineering as a distinct profession is relatively new; 50 years ago the mining engineers usually did the work in this field; their work is still necessary and is now called "extractive" metallurgy. This consists of supervising the concentration or leaching of low-grade ores, the smelting of ore or concentrates into crude metal and its refining into commercial purity, the production of mill shapes such as sheet, tubing, plates, rails, bars, wire. In the last mentioned field the metallurgical specialist has much in common with the mechanical engineer.

To understand the present field of metallurgy, we must expand this old and relatively narrow field and consider at least three others (all very important indeed): *(a)* Fabrication metallurgy, *(b)* research and control, and *(c)* metallurgy of atomic power and weapons.

Fabrication Metallurgy – The general industrial use of specialists in the field of metals engineering had its first real impetus early in World War I – 40 years ago. It was necessary for all sorts of plants which had been fabricating tools, utensils and machinery to turn out guns, ammunition, armor, and all kinds of ordnance. Many items required the use of alloy steel, precisely controlled heat treatment, and close inspection – all of which were beyond the experience of the American metal-consuming industries of that era, whose production was based on the use of shapes of unalloyed steels or simple alloys secured from the mill metallurgist – the extractive metallurgist mentioned above – already possessing the hardness, strength, toughness or other property desired for the part to be made. World War I, therefore, started a revolution in metal fabrication methods which is still under way and has required an army of educated men who are capable of selecting the correct metallic materials, of planning their most economical fabrication routines, of supervising their heat treatments for strength and toughness, and the final surface treatments for size and appearance. These fabrication metallurgists constitute by far the largest group of metallurgical engineers at the present time, and are found in foundries, forge shops, stamping plants, welding departments and fabrication operations in *all* metal-using industries, ranging from those making electron tubes to huge electric generators, from tricycles to automobiles, from diesel locomotives to aircraft, from jewelry and cutlery to steam shovels, from fountain pens to business machines. The insistent demand for such specialists in metal fabrication has absorbed many engineers originally trained as mechanical engineers, chemical engineers or civil engineers.

There will undoubtedly be ten such jobs in the United States open to every metallurgical engineer with a Bachelor of Science degree who will graduate during the next decade.

Research and Control (to which might well be linked teaching) – These men are sometimes called "physical metallurgists" because their training is based on physics and chemistry of metals, the two sciences being closely geared together. Physical metallurgists have come into prime importance in the last 30 years, ever since it became evident that the fabrication metallurgist, described above, needed some scientific principles to correlate his "practical" findings, and that industry has an insatiable appetite for new alloys, specialized treatments, and more economical fabrication processes which the physical metallurgist might discover. Every large unit or segment of the American metal-consuming industry has a well equipped laboratory organization to which are submitted problems of "applied metallurgy" and problems in "fundamental metallurgy". Examples of the former would be a new malleable cast iron, malleable as-cast (that is, without requiring heat treatments days long to give it the best machinability and toughness); or a manufacturing method for a typewriter type-bar by accurately pressing a mixture of powdered iron and graphite and properly sintering and heat treating the compact. An example of research in fundamental metallurgy might be to analyze atomic rearrangements in steel during a rapid quench so that a heat treatment routine could be formulated likely to give necessary strength with the least damage to its toughness.

It is obvious that the metallurgist in the laboratory must utilize the most advanced types of investigative apparatus. He examines the grain structure under a high-power microscope; he probes into the atomic architecture with X-ray diffraction machines; he analyzes for trace impurities with spectrographs or Geiger counters; he determines the mechanical and physical properties; he studies their resistance to ordinary corrosion or high heat; he must draw upon the specialized knowledge of scientists in many other fields. Men capable of such work almost always require post graduate training – a Master's or a Doctor's degree.

These men also have another most important field also open to them – teaching. A recent sur-

vey showed that about 65 Ph.D.'s in metallurgy are being graduated each year, yet in the summer of 1955 there were 55 existing vacancies on our university faculties!

Atomic Metallurgy – The "old" metals, such as iron and copper on which our industrial civilization is founded, are ten or eleven in number. They are relatively widely spread over the earth's surface, and are comparatively easily reduced from their ores. This leaves about 55 rarer or "newer" metals which are much more difficult to come by. The properties of a few of them are only recently becoming known – for example, germanium is now used for transistors which perform like vacuum tubes. Of extraordinary importance are the elements heavier than lead, which are all radioactive. Radium was the one earliest discovered; the most potent is uranium – the heaviest natural element – and plutonium, a man-made metal even heavier. Large numbers of metallurgical scientists and engineers – literally thousands – are employed by the U.S. Defense Department in devising atomic war heads and missile systems to use these explosive metals, and by the Atomic Energy Commission and the electrical and public service industries to design and construct machinery for generating heat and power from them. These devices operate at such extremes of temperature, pressure and corrosive environment that the resources of the most intelligent metals engineers are taxed to the utmost.

All metallurgical engineers are not confined to the reduction, production, and research departments. Many hold other types of positions in the field. Some specialize in technical writing and editing or patent work. Others work in metal sales and service, marketing and purchasing. Managers and administrators in the metal industries are among the highest paid of our business men. Some companies employ metallurgists who design plants, machines and other equipment. A few metallurgists, as consulting engineers, sell their services and information to various firms – many of them small – which do not employ full-time specialists.

Qualifications

Before deciding to enter the field, the prospective metallurgist of high-school age should survey himself carefully to see if he has the necessary aptitudes and qualifications. He will need the ability to undergo a long course of training which does not stop when he gets his degree on graduation day.

In preparation for college, the future metallurgist should take high-school courses in plane and solid geometry, algebra, chemistry and physics. In addition, he ought to have a definite interest in metals and their utilization in American industry. If he is intrigued by chemistry, electricity, machinery, aeronautics, communications, ordnance – any of them will lead into a metallurgical career. But especially if he is interested in things basic to *all* of them—the business of making and using metals for tools or equipment or machinery or structures – *then* he should set his sights on metallurgical engineering!

It will take him four years in college to earn a degree of Bachelor of Science in metallurgical engineering. Necessary courses here include higher mathematics, physics and mechanics; advanced inorganic chemistry; English; economics; and all available courses in metallurgy as defined above. If he decides to continue into graduate school he will specialize in some branch of metallurgy and will begin to have a part in metallurgical research.

However, not all metallurgists in industry have gone through college, but such training is preferable, and the trend is for college-trained metallurgists to get far better salaries. Other metallurgists hold degrees in some related fields of engineering, such as chemistry or mechanical engineering.

Although only a few women have entered the field to date, there are many desirable places open to them in the metallurgical research laboratories.

Opportunities

As will be evident from the description above, almost every American industry offers many opportunities to the newly trained metallurgist. He will find openings in all kinds of plants making iron and steel. Nonferrous metal industries (aluminum, copper, magnesium, zinc, titanium) also offer fine opportunities for employment. Machinery and all transportation equipment industries need metallurgists. Federal agencies also use them, as do nonprofit research establishments which have metallurgical divisions. University teaching positions are open to metallurgical engineers who hold advanced degrees. Jobs for metallurgists are obtainable in every state in the Union.

Method of Entering

Today the new metallurgist has no difficulty in finding a job. Every member of the 1956

graduating class had his choice of several attractive offers made to him by recruiting officers from large industrial firms. Lists of openings in the Civil Service are available from the various government agencies. Engineering and technical societies, such as the American Society for Metals, the American Institute of Mining, Metallurgical and Petroleum Engineers, the American Foundrymen's Society, maintain placement bureaus – as does also the alumni association of your alma mater.

Advancement

The beginner will probably work in the laboratory or as a junior metallurgist in an operating department until he has found his place in the world of metals. Many progressive firms insist that he take intensive courses of training (at company expense) in appropriate specialties. Then promotion will lead him up the engineering ladder. With ability and the right breaks, he may in time become chief metallurgical engineer, or he may transfer to planning, administrative, or executive work in the industry.

Metallurgical engineering, far from being an isolated profession, is related to many similar fields – such as mining (for the extractive metallurgist), mechanics (for the production metallurgist), chemistry (for the research metallurgist) and physics (for the atomic metallurgist). Other allied fields are ceramics, petroleum and gas, industrial and safety engineering. The trained metallurgist is also found occupying important supervisory positions, many in the fields of electrochemistry, electroplating and finishing.

Earnings

A recent survey of American Society for Metals showed the wage offered in the spring of 1956 for graduate metallurgists after a four-year course leading to a bachelor's degree ranged from $375 to $450 per month. Those who have masters' or doctors' degrees in metallurgical engineering are offered $100 to $300 more.

Progress in any organization obviously depends upon the man's own ability to grow into wider responsibilities. A survey recently made by the Advisory Committee on Metallurgical Education of the American Society for Metals showed that, on the average, salaries progressed steadily with time of service for the first 15 years after graduation. Figures from the U.S. Bureau of Labor Statistics indicate that salaries paid to metallurgists are about 10% higher – on the average – than those paid to engineers in other categories.

Metallurgy in the Future

About all that can confidently be said about the future of metallurgy (and the opportunities for intelligent men) is that its expansion in the fields already occupied and its progress into wholly new ones are almost without limit. Consider the situation 50 years ago: We were in a world of steel and cast iron and simple copper alloys such as brass and bronze. The automobile has brought alloy steels, sheet steels and revolutionary finishing methods. Telephone, radio, television and radar have brought magnetic materials, superconductors, and electron emitters. The airplane has brought light metals (strong aluminum alloys, magnesium alloys, titanium alloys). The atomic age has fulfilled the alchemist's dream – we transform one metal into another, and are using a galaxy of metals such as zirconium, beryllium and thorium, never before produced except as curiosities. The production of plastics and synthetic fibers depends upon metal equipment of highest strength and corrosion resistance. The farmer has vastly improved tractors and labor-saving equipment for his fields and dairies. The businessman depends on complex machines made of metal for accounting and correspondence. The housewife has a thousand helpful servants made of metal to take the place of the vanished maid. Every man-made thing you see, every man-made thing you use, depends on the intelligent application of tools, modern metals and economical fabrication.

Can anyone believe this progress will stop?

For Additional Information

American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

American Institute of Mining, Metallurgical and Petroleum Engineers, 29 W. 39th St., New York 18, N.Y.

Engineers' Joint Council, 29 W. 39th St., New York 18, N.Y.

Society for the Promotion of Engineering Education, University of Pittsburgh, Pittsburgh 13, Pa.

National Council of State Board of Engineering Examiners, Drawer 1404, Columbia, S. C.

National Science Teachers' Assoc., 1201 16th Street, N.W., Washington, D. C.

For Further Reference

"Your Career in Metallurgical Engineering," American Society for Metals, 7301 Euclid Ave., Cleveland 3, Ohio.

Pamphlet elaborating the topics briefly discussed herein, and containing a list of American and Canadian colleges and universities which give degrees in metallurgy.

Vibratory Polishing of Metallographic Specimens

By F. M. KRILL*

A new method of polishing aluminum alloys with vibrating equipment has reduced the labor and skill required and increased the quality of surface obtainable. (M 21, Al)

MANUAL polishing of metallographic specimens of aluminum alloys is a time-consuming operation and requires a considerable amount of skill to obtain satisfactory results consistently. We process a large number of samples in our laboratory and, until recently, used the conventional method of fine polishing on a rotating wheel covered with a soft nap cloth and a paste of magnesium oxide and water as an abrasive. A new method of final polishing by vibration was adopted and has not only saved labor but has also produced better surfaces than those obtained by hand polishing methods.

Samples are ground and polished by the usual hand methods up to the final polishing operation. With the vibratory polisher, the conventional soft nap cloth is used but it is cemented to the inside of a bowl which forms the polishing head and which is caused to vibrate by an electromagnet. The abrasive is applied to the moistened cloth and the samples are loaded into the bowl. The vibratory motion of the head polishes the specimens and at the same time causes them to rotate and revolve so that the polishing direction is changed constantly. Weights are added to the specimens to speed the polishing action. After polishing, the samples are removed, washed, and are ready for examination.

The machines are made by the Syntron Co., Homer City, Pa., and consist of a stainless steel bowl, a heavy base containing the electromagnet, and a controller for adjusting the amplitude of the vibration. The machines operate on 60-cycle current and are made in bowl sizes from 5 to 36 in., the small machines being used in this laboratory. The vibratory motion has a horizontal rotational component which provides the polishing action, and a smaller vertical component which combines with the first to move the samples around the periphery of the bowl. The vertical movement on our 5-in. machine is 0.006 in. The horizontal rotational movement is zero at the center and 0.014 in. at the circumference of the bowl. The operation is essentially noiseless, consisting of a low hum in the electromagnet and a slight clicking of the samples in the bowl.

The advantages of this method of polishing are many, the chief being the reduced amount of hand labor required. Hand polishing on a rotating wheel requires the development of a great deal of skill before satisfactory samples can be produced. Uniformity of polish is particularly difficult to attain since the pressure and wheel speed are varied at will by the operator. The vibratory machine, however, has a calibrated dial for controlling the motion and the pressure is applied by weights. These are in the form of

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Vibratory Polishing Machine and Controller

metal rings which slip over the specimens and are fastened by set-screws. A typical weight for a 1-in. sample is 90 g. Heavier weights cause faster polishing but lighter weights produce a smoother surface. A surface satisfactory for most examinations can be obtained by polishing for 30 to 60 min. Longer periods will produce a surface far superior to that obtainable by hand polishing.

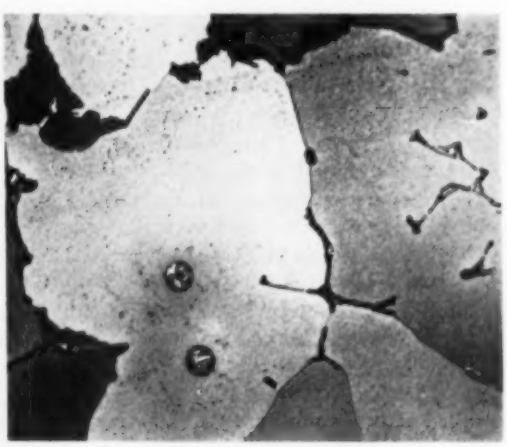
A rotating wheel tends to throw off the abrasive material so that additions must be made periodically. The vibratory machine retains the abrasive which, in practice, is used over and over for additional batches of samples. More than 50 samples have been run on a machine without renewing the abrasive and with no apparent reduction of the polishing action. The tendency for the cloth to dry out is minimized by covering the bowl during polishing. There is no tendency for the sample to "dig in" or be thrown from the wheel, as in hand polishing.

Some of the difficulties with hand polishing are overcome by the use of automatic polishers for rotating wheels. I have had only limited experience with these but some advantages of the vibratory method are immediately apparent. One of the principal difficulties with automatic polishing machines is that the samples cannot be polished individually, the machines usually having a holder for 3, 6 or 12 metallographic specimens. Samples placed in these holders must have the surfaces to be polished lying in a common plane. This usually requires that they be placed in the holder before the coarse grinding operation and be left there until the final polish has been obtained. They must, of course, be the proper size to fit the holder and usually require plastic mounting. Samples rough-ground by hand are often beveled too much to be placed in such a holder for final polishing.

On the vibratory polisher samples may be polished individually or in groups and can be removed or added at will. Various diameters, lengths and shapes of specimens may be polished together and they usually need not be plastic-mounted. The machine is cheaper than rotating wheel equipment, requires very little bench space and gives longer cloth and abrasive life. The polishing head is easy to clean and the moving parts require no lubrication and are not subject to wear.

There are, of course, some disadvantages. A single sample can still be prepared more rapidly by hand polishing, since the polishing period for the vibrator is about a half hour. The polishing cloths must be cut by hand and changing them involves the use of a solvent and cement. The method has not yet been successfully applied to all the aluminum alloys; some additional hand polishing is usually required on very soft material. It is hoped that additional experience will result in application of the method to other nonferrous and ferrous alloys with the proper abrasive and cloth combinations. Perhaps the coarser grinding and polishing operations could also be performed advantageously on vibratory machines.

Machine-Polished Sand Cast Aluminum Alloy 195-T 6, Showing Overheating. Keller's Etch; 250 ×



Rapid Chemical Analysis With the X-Ray Spectrograph

By A. M. REITH and E. D. WEISERT†*

X-ray spectrographic analysis has replaced wet chemistry techniques for routine determinations of difficult-to-handle elements. The results are accurate and analysis is both rapid and inexpensive. (S 11)

More than 600 chemical analyses of cobalt, nickel and iron-base alloys must be made every day at the laboratories of the Haynes Stellite Co. and any method that increases speed or reduces cost without sacrificing accuracy is quickly adopted. Installation of an optical spectrograph in 1948 resulted in both cost and time savings for the analysis of many elements in concentrations less than 5%. However, many analyses are required of elements present in amounts up to 30%. The higher concentrations are not readily handled by optical spectrography, but have proved exceptionally amenable to X-ray spectrographic analysis, a technique we adopted a year ago.

For X-ray spectrography, the specimen to be analyzed is bathed in an intense beam of X-rays which excite the atoms near the surface of the sample sufficiently to cause them to fluoresce and emit secondary X-radiation. This secondary radiation is characteristic of the element from which it has been emitted and its intensity is proportional to the amount of that element present in the sample.

The fluorescent radiation is analyzed with a crystal, such as rock salt, which acts as a grating and diffracts the characteristic X-rays according to Bragg's law so that intense reflections from the crystal will be received only at discreet values of the Bragg angle. The values of the angles at which intense reflections occur are dependent on the wave length of the radiation.

As a measure of the amount of element present, the intensity of an appropriate reflection is determined with a radiation detector such as

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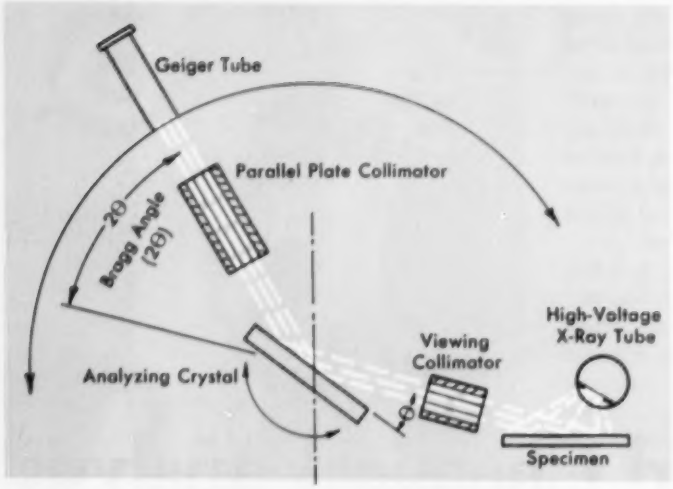


Schematic Diagram of X-ray Spectrograph

a Geiger-Muller tube. Within a wide operating range, these devices give a linear response to the intensity of the incident radiation in the form of electrical pulses. The pulses and their rate of accumulation are counted by appropriate electronic scalers. A parallel-plate collimator just ahead of the detector allows the Geiger-Muller tube to receive only that radiation which is reflected at the appropriate angle as measured from the beam of radiation striking the crystal.

Qualitative analysis of a specimen may be accomplished by scanning – that is, moving the radiation detector along an arc while the crystal is moved at just one-half the angular rate. In this manner, a record of all occurring diffraction peaks will be obtained and may be related to elements present in the specimen.

Quantitative analysis is accomplished by presetting the equipment to a diffraction peak for the element of interest. The peak chosen will be one that is strong and free from interference by peaks corresponding to other elements. The instrument is calibrated against a previously determined working curve of counting rate versus weight per cent of the element present in a given alloy. Once calibrated, the instrument is used to determine the intensity from the unknown sample. This is usually done by measuring the time required to accumulate a fixed number of counts. The counting rate is then translated into weight per cent by use of the working curve.

Currently 29 different alloys are being analyzed by the X-ray spectrograph for nine different elements at levels from 2 to 28%. These are indicated by the elements in italics in Table I. At present, approximately 1100 determinations per month are made by the X-ray method.

The first elements considered for transfer to X-ray analysis were those which require the most difficult or lengthy wet chemistry techniques. For example, analysis of tungsten in the cobalt-base Haynes alloy No. 25 requires more than 24 hr. by tedious wet procedures and even this lengthy method has sacrificed some accuracy to avoid an even longer (though more precise) technique. With the X-ray spectrograph the analysis time is reduced to about 20 min. from the receipt of the unprepared sample. In addition, accuracy is improved. Also, once analyses have begun on a series, one specimen may be processed about every 3 min.

The working curves are prepared with standard samples which are analyzed several times by the most careful wet chemical tech-

Table I – Nominal Content of Elements Determined by X-Ray Spectrograph
(Indicated by Figures in Italic)

	Cr	W	Fe	Mo	Ni	Co	Other
				Iron-Base Alloys*			
Haynes Alloy 93	*17*	—	Bal.	*16*	—	*6*	*2 V*
Multimet alloy	*21*	2.5	Bal.	*3*	*20*	*20*	1 Cb + Ta
				Nickel-Base Alloys			
Hastelloy Alloy B	—	—	*5*	*28*	Bal.	—	—
Hastelloy Alloy C	*15.5*	*4*	*5*	*16*	Bal.	—	—
Hastelloy Alloy F	22	—	*20*	*65*	Bal.	—	2 Cb + Ta
Hastelloy Alloy X	22	—	*18*	*9*	Bal.	—	—
"Thet" Alloy	25	7	*3*	*3*	Bal.	*12.5*	*2.5 Mn*
GMR-235	*15.5*	—	*9*	*5*	Bal.	—	*2 Ti*, 3 Al
				Cobalt-Base Alloys†			
Haynes Stellite 31	25.5	*7.5*	—	—	*10.5*	Bal.	—
Haynes Alloy 25	20	*15*	2	—	*10*	Bal.	—

*Also stainless steels (300 series), 11 alloys analyzed for Ni from 8 to 22%.
†Eight other cobalt-base alloys containing about 30% Cr are analyzed for W ranging from 8 to 18%.

niques available. The averaged values are plotted against the counting rate obtained from the X-ray spectrograph for the corresponding standard. In general, a straight line results.

Standards are usually prepared by selecting a base heat of a given alloy that has a low content of the element of interest. Remelting this base with successively higher additions of the element produces a series of specimens of comparable matrix but enriched in the added element. However, satisfactory working curves were obtained for the nickel-base Hastelloy alloy C when four elements were varied in concentration simultaneously in four heats of the alloy. While the nickel content was held fairly constant (53.10 to 54.00%), chromium was varied from 14.00 to 16.14%, tungsten from 3.59 to 5.60%, iron from 4.56 to 7.77% and molybdenum from 15.50 to 18.75%. Using this technique, only four standard samples were required to obtain four working curves. If only one element had been varied each time, 16 heats would have been required. Verification points may be added to the working curve by selection of appropriate routine samples for rigorous wet analysis. It should be noted that the technique of simultaneously varying several element concentrations may not be satisfactory if the absorption characteristics of the matrix are appreciably altered with respect to the radiation of interest. Nevertheless, this economical technique of obtaining standards should be widely applicable.

Another economy in standards resulted when it was shown that nickel in the 300 series stainless steels could be successfully handled with one set of standards and one working curve for the whole family of 11 steels. The nickel content varies from 8 to 22% in this group. A similar circumstance exists with the cobalt-base alloys in which eight different alloy grades can be analyzed for tungsten from 8 to 18% with one set of standards for the whole group. Still further savings are realized because of the nondestructive nature of the method so that standards are, for all practical purposes, permanent.

North American Philips Co. 50-Kv. X-Ray Spectrograph

Table II – Comparison of X-Ray, Routine Wet and Umpire Analyses

Element	X-Ray	Routine Wet	Umpire Wet	X-Ray, % Error	Routine Wet, % Error
W	18.00	18.20	18.03	0.17	0.94
	6.85	6.92	6.80	0.74	1.8
Mn	2.44	2.38	2.41	1.2	1.2
Ni	9.65	9.92	9.68	0.31	2.5
	21.45	21.38	21.55	0.46	0.79
Cr	15.75	16.15	15.81	0.39	2.1
	22.87	22.63	22.80	0.31	0.75
Co	15.05	14.94	15.00	0.33	0.40
	6.35	6.19	6.30	0.79	1.7
Fe	4.26	4.39	4.35	2.1	0.92
	17.20	17.10	17.25	0.29	0.87
	6.65	6.15	6.49	2.5	5.2
Mo	15.92	15.56	15.85	0.44	1.8
	9.95	10.12	9.95	0.00	1.7
	3.65	3.48	3.62	.83	3.9
V	2.14	2.10	2.11	1.4	0.5
Average % Error				0.77	1.69

Precision was investigated by ten consecutive exposures of the same specimen. The sample was removed and replaced for each new run. Molybdenum in Multimet alloy (N-155) has a normal concentration of 3%. When 51,200 total counts were accumulated in each of ten runs, a range of 3 counts per sec. and a standard deviation of 0.8 count per sec. were obtained. These values are equivalent to 0.03 and 0.008% molybdenum, respectively. The nominal 10% nickel in Haynes alloy No. 25, in a similar experiment, gave a range of 12 counts per sec. (0.22% Ni) and a standard deviation of 4.8 counts per sec.

(0.08% Ni) when only 25,600 counts were accumulated. If 102,400 total counts are accumulated, the standard deviation is only 1.6 counts per sec., equivalent to 0.03% nickel. This increase in precision is a result of the statistical behavior of radiation detectors.

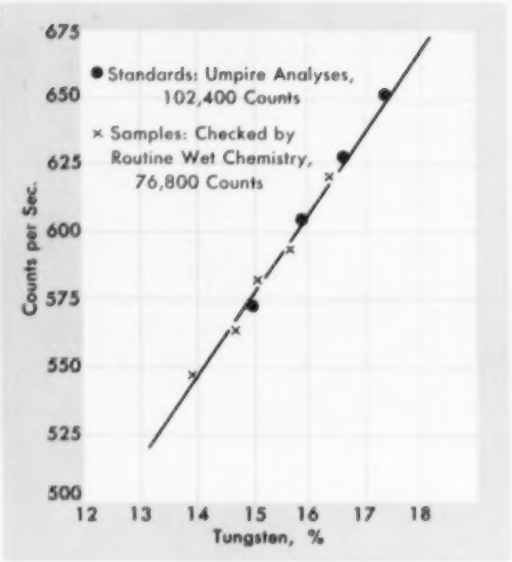
The probable error attributable to the random arrival of X-ray quanta at the detector window will decrease as the total number of counts accumulated increases. Thus, if 3200 counts are accumulated, the probable error caused by this effect alone is 1.2%. If 102,400 counts are accumulated, the probable error drops to 0.2%. For this reason, the largest number of counts consistent with reasonably brief counting times should be accumulated.

For most of the determinations shown in Table I, 76,800 counts are accumulated. For weaker reflections, such as those obtained from low levels of vanadium, titanium and manganese, only 25,600 counts are accumulated to avoid excessive counting time. In routine operation, the counting time is usually 2 to 4 min. Accuracies are about ±1% or less of the nominal element concentration.

The method appears to be generally more accurate than the results obtained by routine wet chemistry, as indicated in Table II which compares some results of routine X-ray and routine wet analyses with the umpire wet chemistry results. The latter data are obtained by very accurate chemical procedures and are averages of several determinations. In general, the X-ray results are in closer agreement with the umpire values than are the wet chemical analyses.

For precise quantitative results, it is necessary to expose a consistent area of the specimen in a consistent manner. A standard size specimen is desirable and is most convenient for metal producers. A disk-type specimen, 1¼ in. in diameter and about ⅜ in. thick, is used. This can be cast to size in investment or sand molds or it may be chill cast in bar form and sliced to size. Any variation in the positioning of the specimen can lead to errors resulting from altering the geometry. Such alternations will affect the intensity of the diffracted peaks. The area of the specimen exposed must be the same for each analysis since it determines the total radiation incident on the analyzing crystal. Both of these requirements are met with a rigid specimen holder which reproducibly positions and masks each specimen.

The variable of surface finish was thoroughly investigated by running reproducibility checks on specimens finished with 40, 120, 220, 320, 400, 600 grit and 600 grit plus electrolytic etching. The coarser finishes produced a large error if the grinding furrows were not always positioned in the same orientation with respect to the X-ray path. All of the specimens were run in four orientations, 0°, 90°, 180° and 270°, with respect to X-ray path, and the orientation effect persisted up to the 600-grit finish. Equally good reproducibility could be obtained with the more convenient 120-grit finish when the grinding marks were consistently oriented. Thus, there was good agreement between the 0 and 180° orientations and between the 90 and 270° orientations. Standard practice consists of a 40-grit roughing polish followed by a 120-grit final finish with the grinding marks parallel to each other and to the X-ray path.



Working Curve for Tungsten in Haynes Alloy No. 25. 120-grit finish; W-Lβ_1, 26.27° (2θ); 50 kv., 30 ma.; tungsten tube; NaCl crystal

Several calibration techniques are possible; however, the method in routine use at Haynes Stellite Co. will be described. After the circuits have had ample warm-up time (at least 30 min.), the tube voltage and current are adjusted to the values used in determining the working curve. Determinations are then made on two of the standards and a line parallel to the working curve and through the two points is used to determine the unknowns. Since this calibration must be repeated for each different element

Specimen Rotation Device and Typical Specimens

analyzed, a series of samples are analyzed for a given element as a batch.

An unusual effect was encountered upon installation of the X-ray equipment in close proximity to the optical emission spectrograph. The radio-frequency energy generated during sparking of the specimens was sufficient to trigger the X-ray detector circuit in a sporadic manner. The spurious counts were eliminated by shielding the high-voltage lead to the Geiger-Muller tube with grounded copper braiding.

Another unusual effect was encountered when analyzing investment-cast alloy slugs for tungsten. The slow cooling rate of the investment casting process leads to very large grains in the sample. As a result, in certain positions, such a sample will not only fluoresce but also diffract the tungsten excitation radiation in the direction of the analyzing crystal. Since the crystal will not distinguish the two sources of radiation, an excessive counting rate will be obtained. The error is sensitive to the orientation of the specimen since in most orientations the diffracted radiation will not reach the crystal. This problem was solved by constructing a device which would rotate the specimen during analysis. Since diffracted radiation is now incident on the crystal so small a portion of the total analysis time, the effect is diminished to the point of avoiding significant errors. The sample is rotated at 77 rpm. so as to be asynchronous with the X-ray current. It should be noted that rotating the specimen also eliminates the orientation effect caused by the grinding marks.

Errors caused by segregation are avoided, since the area of the sample involved is quite large – about ½ sq.in. Certain alloys especially susceptible to this error in optical spectrography are handled readily by the X-ray method.

The cost of an X-ray spectrographic determination is about one-fourth that of the wet chemical procedures. However, a true evaluation of the economic value of the method must include the savings which are realized by the speed with which determinations can be made. Rapidly executed control analyses can frequently avoid costly off-chemistry heats.

Maintenance costs on the equipment have been minor. At the time of this writing, over 6000 hr. has been accumulated on the original tungsten X-ray tube and only normal replacement of electronic tubes has been necessary.

The equipment, as used, has the limitation that only elements of atomic number 22 (titanium) or higher can be analyzed. With a helium path in place of an air path for the X-rays to follow and with a special detector and crystal to handle the longer wave-length radiation, it should be possible to analyze elements as low as atomic number 13 (aluminum) or lower. A highly mechanized version of the X-ray spectrograph has recently become available which offers substantially increased accuracy, decreased counting time and simplified automatic operation.

The X-ray spectrograph has proved to be a valuable analytical tool in the Haynes Stellite laboratories. The advantages of the method include rapid results, lower cost, good results at high concentration levels, nondestruction of sample and minimum standard preparation. These are advantages that should interest many analytical laboratories in the metals industry.

Better Barrel Finishing With Improved Abrasives

*By WILLIAM E. BRANDT**

The new fused chips and bonded shapes of aluminum oxide and the wide variety of chemical additives available have made tumbling a precise method of cleaning and finishing metal components (L 10)

FOR MANY years, tumbling or barrel finishing has been used as an inexpensive method of cleaning and simultaneously removing sharp edges from castings, forgings and stampings. It is an effective process and the only equipment required is a motor-driven container. Originally, the rough work pieces were inserted along with cast iron slugs or "jacks", or even pieces of scrap, rocks or broken grinding wheels, and rotated until the edges felt smooth. Slight projections were removed or, more often, peened over during the tumbling and sharp corners were rounded off. Dimensional control, particularly of the corner radii, was virtually unattainable.

Because of the low cost of tumbling, much effort has been spent to obtain more precise control and greater versatility. The first major advance was the development of fused aluminum oxide chips as an abrasive to replace the miscellaneous materials previously used. With this fast cutting abrasive, it became possible to remove burrs rather than peen them over and to deburr large quantities of parts quickly. By proper selection of chip size, uniform radii of predetermined size could be developed at corners.

The fused chips were good but until a few years ago had several major disadvantages. They were porous and fractured easily so that no matter how carefully they were screened initially, size control during processing was impossible. Without good chip size control, precision parts cannot be handled properly, especially when they contain blind holes. Another problem was impregnation of the metal parts with aluminum oxide. The impregnation interfered with subsequent finishing operations and caused erratic behavior in soldering, brazing or welding.

In 1948 a chip manufacturer felt that impregnation might be eliminated by chemical means and asked us for advice. After some years of research, we developed a series of chemical additives with which we could prevent impregnation, remove it as fast as the oxide was being deposited or allow it to accumulate but remove it in a bleaching operation before the coloring or burnishing run. Even though we were able to work with fused aluminum oxide chips on any metal or alloy and obtain satisfactory results, we felt that the chip itself would have to undergo a rather complete renovation. Our recommendations were that the porous outer rind of a fused aluminum oxide ingot should not be used for chip manufacture. In addition the crystalline structure of the fused aluminum oxide should be controlled inasmuch as it seems to govern breakdown and fracture. Chips should be of blocky shape, properly rounded and correctly sized so that the consumer can use them as received.

Today all the foregoing improvements have been made and we have a fused aluminum oxide chip which represents the ideal abrasive for precision barrel finishing yet costs no more than its badly handicapped predecessor. By mixing appropriate chip sizes, the workpieces can remain in the barrel until finally finished. There

*Vice-President, Lord Chemical Corp., York, Pa.

Fused Aluminum Oxide Chips Used in Precision Barrel Finishing

is no unloading and reloading of work and abrasive. Only compounds are changed and the load rinsed between cycles of a multiphase run. Fracturing has been virtually eliminated. In one instance, 500 lb. of chips were run continuously in a 6½-cu.ft. compartment at 16 rpm. for 26 hr. – only 0.18 g. of fracture residue was produced.

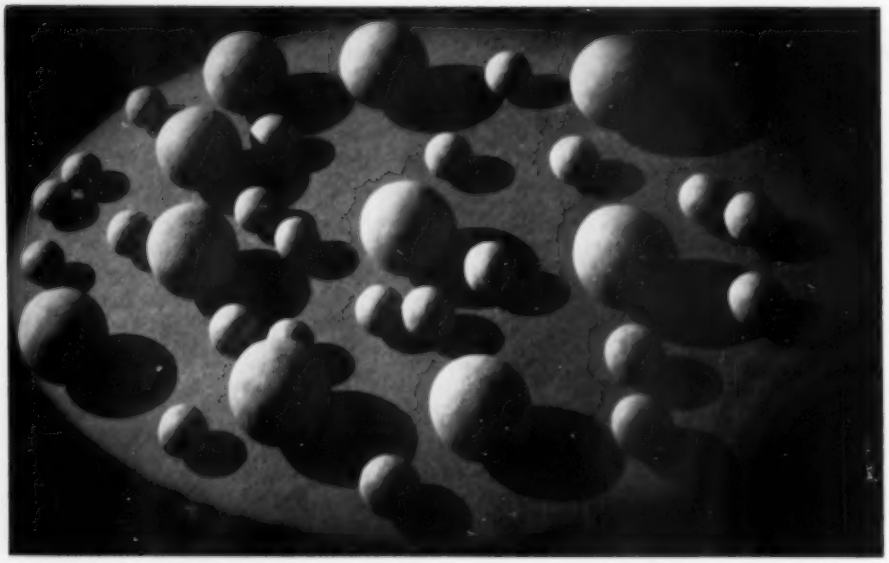
This chip will not only descale, deburr, grind and fine-finish but will also produce burnishes which often cannot be matched with steel shot or steel ball operations. The same chips may be used for both by selection of the proper compound. The chips gradually become loaded when used for burnishing and will not cut. However, a 3-min. run with a very small amount of the proper detergent at high water level will restore the original sharpness.

There are only a few kinds of parts that cannot be finished with aluminum oxide chips. For example,, in processing small gears with fine deep-rooted teeth, the chip will be so shielded as to be unable to do any work. In this instance, the proper grade of shot or pins should be used. The same is true of any enclosed surface completely shielded against the gravity pressure of the load. As long as the working surface can be reached through suitable openings, however, some special abrasive can usually be found to do the work with the right compound.

Fused aluminum oxide chips will work on all metals and alloys, no matter how soft or hard. The surfaces will be chemically clean if the right compound has been used and will be suitable for plating, soldering, brazing or welding.

One of the latest developments in the abrasive chip field is the bonded shape made from fine grains of aluminum oxide joined with silica or garnet. When it is properly made, the bonded chip will last longer than the pure fused aluminum oxide chip because the bonding material does not cut. Therefore, it takes longer time cycles to do the same work with the bonded chip. If the chips are made with too great a propor-

Bonded Triangular Shapes Developed for Faster Cutting



New Bonded Abrasive Spheres Produce Finer Finishes and Better Color

tion of fines, they will powder, fracture or wear away with excessive speed. They tend to impinge and are not suitable for very fine finishing, However, they will produce a beautiful color in burnishing operations.

Bonded triangular shapes have recently become available and may be used in applications where wedging is a problem or where extremely fast cutting is required. Because of the flat surfaces, cutting rates are almost twice as high as with fused chips. Unfortunately, they also break down faster. Triangles cannot very well be used for coloring and burnishing and usually produce a matte finish.

Under development at the present time are abrasive spheres made of bonded aluminum oxide. They are of finer texture than the triangles and will, therefore, yield finer finishes and better color. Their shape precludes fast cutting but reserves a place for them in special applications.

In all precision barrel finishing methods, a liquid carrier containing chemical compounds is essential. The compositions of the additives are jealously guarded secrets of the individual manufacturers and special mixtures are supplied for each alloy and kind of finish required. The additive must protect the workpiece against corrosion, pitting and impregnation, hold the soil in suspension, keep the abrasive clean and sharp, and be self-rinsing. Many additives also contain some fine abrasive in suspension in order to increase the speed of deburring, grinding and stock removal. Such abrasive mixtures have wide application in self-tumbling operations or in tumbling with soft steel shot.

A good abrasive mixture should contain up to 80% of the properly graded, uniform and uncontaminated abrasive material. Reclaimed materials, sweepings and dust collector fines should not be used. In our experience silicon carbide has proved unsatisfactory for processing very hard metals. While it takes a very sharp initial bite, it becomes ineffective very quickly in tumbling because of its friability. Aluminum oxide grain is quite suitable for a wide range of applications in abrasive compounds.

Aluminum oxide may also be used for finishing soft alloys with the necessary additives to prevent impregnation. If there is even a small amount of impregnation that is not completely removed, there will be considerable difficulty in subsequent machining operations. Often such a condition is intolerable from the standpoint of tool maintenance.

Such difficulty can be entirely avoided with the proper nonabrasive compound. When an abrasive compound is necessary, however, a softer and finer abrasive material should be used. If there is still some impregnation, a simple 15 to 20-min. run with the proper bleaching compound will remove it completely. Bleaching operations usually precede the burnishing or coloring run, especially if the work is to be subsequently plated.

Book Review...

Modern Theories of Physical Metallurgy

*Reviewed by R. W. LINDSAY**

ELECTRONS, ATOMS, METALS AND ALLOYS, by William Hume-Rothery, Philosophical Library, New York, 387 p., 1955. $10.

THE STRUCTURE OF METALS AND ALLOYS, by William Hume-Rothery and G. V. Raynor, The Institute of Metals, London, 363 p., 1954. $5.50.

Modern theories about metallic structure and how it influences the behavior of metals are too often expounded in language that is crystal clear to physicists and mathematicians but far too technical for the metals engineer in industry who might have immediate use for the information disclosed. The language barrier is not insurmountable, however, as indicated by these new editions of two books on the subject of physical metallurgy.

"Electrons, Atoms, Metals and Alloys" is written as a dialogue in which a younger person with a knowledge of the modern theory of solids and the metallic state is attempting to answer the questions of an older metallurgist from industry who has had a standard education in chemistry, mathematics and elementary physics.

As the title implies, the subject of the metallic state is treated in very orderly and progressive fashion. First there is a discussion of the nature of the atom and the difference between metals and nonmetallic elements. Next the crystalline nature of a metal is considered, which introduces the problem of dislocations and other imperfections in real crystals. The discussion then turns to the energy distribution of electrons in metal crystals, and the kind of experimental evidence used to confirm theoretical conclusions. The electron theories of metals are presented in such a way that the reader is led from the older theories through to the zone theory of metals. The crystal structure of the elements is explained and this in turn leads to a discussion of atomic bonding and typical metallic structures. The various metallic elements are described and interrelations between such properties as electrical conductivity, atomic diameter, cohesion and magnetism are explained. The problem of plastic deformation is treated in a separate chapter.

The nature of an alloy is considered in terms of the principles of formation of solid solutions and intermediate phases in alloys. The reader will find this to be a very extensive treatment of the principles of alloying.

Some attention is given to radioactivity and natural disintegration, the artificial disintegration of atoms, fundamental particles, the structure of the nucleus and fission of the nucleus. This material has a place in the text because of the relationship of metallurgy to atomic energy.

Metallurgical educators and metallurgists in industry are certain to find much food for thought in the author's discussion of the shortcomings of metallurgical education and the relation of industry to these shortcomings.

"The Structure of Metals and Alloys" is strongly recommended for students and industrial and research metallurgists interested in the principles of alloy formation and the physical and mechanical properties of metals and alloys. The first part of the book presents a condensation of certain of the material given in "Electrons, Atoms, Metals and Alloys" followed by a discussion of the crystal structure of the elements. More than half of the text is devoted to the principles and theories of alloy formation, introduced by a discussion of the atomic radii of the elements. This is important

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"not only because many alloy structures are determined or influenced by the relative sizes of the atoms concerned, but also because they throw light on the interatomic forces which hold the atoms together".

One of the sections that has been added to the new edition deals with the structure of alloys of iron. It should be valuable to the college or university student. The entire field of ferrous physical metallurgy is covered, starting from the metal and moving through a discussion of binary alloying principles, the iron-carbon equilibrium in steels, the decomposition products of austenite and the latest developments in the metallurgy of cast irons. Although much of this will be considered as a review by the practicing metallurgist in the field, the section on iron-carbon equilibrium in alloy steels represents a sound, systematic treatment.

The section on imperfections in crystals and deviations from the ideal lattice includes new material. All physical metallurgists are interested in the mechanical properties of metals and their alloys, and recently much has been published with regard to the important effects of degree of perfection of the crystal structure. This material seems to be summarized in acceptable fashion and should be of assistance to those who are now studying this branch of metallurgy. It should also be a good starting point for metallurgists in industry who are trying to acquaint themselves with this subject.

The reviewer has found both of these books very useful as reference texts in courses on physical metallurgy. If he were to advise a choice of the one or the other, however, he would recommend "The Structure of Metals and Alloys" as more useful to the industrial metallurgist. "Electrons, Atoms, Metals and Alloys" would be more meaningful to students working for advanced degrees in metallurgy, to people with training in chemistry and physics who are developing a specific interest in metals, and to research workers engaged in synthesizing new alloys.

Precision Measurements of Force

*By ARTHUR C. RUGE**

Strain gage dynamometers have been adopted by the National Bureau of Standards for calibration of loads and forces too large to be handled by proving rings. (Q general, S general)

SINCE its development nearly 40 years ago by H. L. Whittemore and S. N. Petrenko, the proving ring has been used by the National Bureau of Standards as a basic standard for checking the accuracy of weighing and force measuring devices. Its maximum capacity is limited to 300,000 lb. in compression and 100,000 lb. in tension and although several can be used together to calibrate a testing machine of large capacity, there is a practical limit which is below the maximum of the new large testing machines.

Several years ago development of new calibration equipment was initiated by Lyman J. Briggs, director emeritus of the Bureau. The objective was to find a method which would have the accuracy and stability of the proving

*Consultant, Baldwin-Lima-Hamilton Corp., Philadelphia.

The New 3,000,000-Lb. Force Standard Consists of a 225-Lb. Steel Column With Eight Bonded Wire Strain Gages

ring but with a wider range of capacity so that loads as high as 12,000,000 lb. could be measured. The solution was an electrical system of strain measurement which used bonded strain gages.

The strain gage dynamometers are solid steel columns with eight resistance wire strain gages equally spaced around their centers. Four are bonded to the column longitudinally 90° apart and the other four are bonded in transverse positions. The column is flared out at top and bottom to enlarge the bearing areas and a cylindrical protective metal cover is held in place by setscrews through retaining rings around the enlarged ends of the column. The strain gages are connected together to form Wheatstone bridge circuits. A modified Baldwin SR-4 strain indicator is used as a load-indicating device.

Strain gage dynamometers of 100,000, 300,000, 1,000,000 and 3,000,000 lb. have been built by the National Bureau of Standards. These include four each of the two largest sizes. Their accuracies meet the requirements of A.S.T.M. E 74-50 T which provides tolerances of 0.4% for 3,000,000 lb. and 0.3% for 1,000,000 lb. The largest one weighs about 225 lb. which permits easy handling by two men, and its rugged construction permits handling on hand trucks or by crane. The million-lb. dynamometer weighs only about 30 lb. Associated electrical instruments are also readily portable. The large units are expected to reduce the time required for calibrating a 10-million-lb. testing machine by 75% and the cost to 50% of that formerly required for calibration of a testing machine of only 2.5 million lb. capacity.

Much less skill is required of the operator to obtain satisfactory readings under loads that are changing rapidly or that transmit considerable vibration. Furthermore, measurement of load can be made at a remote point and the scale division corresponding to capacity load may be adjusted to match any desired interval.

Although the present measuring instruments are sufficiently sensitive and easy to handle, it is believed that it will be possible to improve their quality and design to meet the special requirements of this type of service. Such improvements will eliminate difficulties in obtaining the required high degree of stability in the strain gages and the measuring circuit and reduce the complexity and cost of the electrical components.

Of significance in connection with the development of new type calibration equipment is the fact that until about 1950 approximately 90% of the elastic calibration devices submitted to the Bureau for calibration were proving rings. Now the volume of calibration work has increased about 100% and load sensing units based on resistance wire strain gages comprise about 30% of the calibration devices and force-measuring units submitted for calibration.

Present practice is to calibrate load-sensitive devices having capacities between 300,000 and 1,000,000 lb. by means of calibrated proving rings in a testing machine of adequate load capacity. Load sensitive devices having capacities between 1,000,000 and 10,000,000 lb. are calibrated by means of the 1,000,000 and 3,000,000-lb. strain gage dynamometers.

Enhanced Properties in 17-7 Stainless

*By M. W. MARSHALL, D. C. PERRY, and N. R. HARPSTER**

High strength-weight properties of 17-7 stainless steel with aluminum, hardened partially by martensitic transformation at −100° F. and further by aging at 950° F., are very useful for aircraft and missile parts working up to 800° F. Brazed honeycomb structures readily lend themselves to this heat treatment. (J 26, J 27, SS)

With the dawn of jet engines and supersonic flight, new materials for aircraft construction were necessary. One of the major requirements was for materials which could be easily formed and still be capable of developing high strengths at room and elevated temperatures. Precipitation hardening stainless steel meets these requirements. It has found wide use, during the past eight years, for structural components in F 84 F, F 86, F 100, F 102, and F 104 fighter aircraft, in the T 2 V-1 Navy trainer, the B 58 bomber, and the P 5 M-1 and P 5 M-2 patrol bombers.

This report covers an important metallurgical advance in the heat treatment of Armco 17-7 PH to attain even higher tensile properties than were previously offered to the aircraft industry. The nominal composition of this precipitation hardening stainless steel is 0.07% carbon, 17% chromium, 7% nickel, and 1.20% aluminum. The composition limits of a stainless steel of this type are much more critical than in the conventional A.I.S.I. types because of the effect of minor elements on the Ms temperature (start of transformation from austenite to martensite).

In the solution annealed state, known as Condition A, 17-7 PH has a microstructure primarily of austenite, but containing 5 to 20% delta ferrite. To develop high strength in this steel, as in other steels, a martensitic structure must be obtained, and in 17-7 PH the austenite can be transformed by either severe cold work or a thermal treatment. Subsequent heating at 700 to 1100° F. results in an additional hardening, believed to be caused by the precipitation of an intermetallic compound (presumably aluminum-nickel). This heating also acts as a stress-relieving treatment.

Condition TH 1050 – In most aircraft and missile applications, fabricated parts are transformed from austenitic to martensitic microstructure by a thermal treatment. However, since the austenite in solution annealed Condition A is stable against martensitic transformation, it must be "conditioned" so transformation will occur at readily obtainable temperatures. Figure 1 illustrates the general principles; it shows the effect of various austenite conditioning temperatures on the Ms point of Armco 17-7 PH. To determine these points, 0.050-in. thick specimens (which had been commercially annealed into Condition A by holding at 1950° F. for about 1 min.) were then held 5 min. at the indicated temperatures prior to cooling. Note that at the lower temperatures (1400 to 1600° F.) where the solubility of chromium carbide in the austenite is low, martensite begins to form on cooling

*Mr. Marshall is senior research engineer and Mr. Perry is research engineer in the Armco Steel Corp.'s laboratories at Middletown, Ohio. Mr. Harpster is research engineer for Armco at Baltimore.

Table I – Chemical Analysis of Five Arc Furnace Heats

Heat No.	C	Mn	P	S	Si	Cr	Ni	Al
A (44433)	0.065	0.91	0.019	0.011	0.45	16.90	7.15	1.10
B (53836)	0.069	0.71	0.021	0.008	0.39	17.15	7.06	1.10
C (54807)	0.069	0.55	0.021	0.011	0.44	17.42	7.04	1.09
D (45534)	0.070	0.71	0.020	0.009	0.29	17.15	7.13	1.18
E (45328)	0.071	0.74	0.019	0.006	0.28	17.01	7.22	1.30

at fairly high temperatures (Ms = + 125 to 200° F.). As the austenite conditioning temperature is increased toward the region where chromium carbide is more soluble, the Ms temperatures are depressed, reaching a minimum value after an annealing temperature of about 1950° F., which is the temperature previously used for solution annealing. Other data have indicated that by raising the temperature further – to 2200° F. – the delta ferrite is increased, which we believe impoverishes the austenite in chromium and increases the Ms temperature.

We therefore use a solution annealing temperature of 1950° F. and an austenite conditioning temperature of 1400° F. so that sufficient transformations can be obtained at 60° F. on cooling. Upon subsequent hardening at 1050° F. the following minimum properties are guaranteed at room temperature for 17-7 PH in what we call "Condition TH 1050":

Ultimate tensile strength	180,000 psi.
0.2% offset yield strength	150,000 psi.
Elongation in 2 in.	6%

These properties are readily developed in the customer's plant by heat treating fabricated parts. In severely cold worked regions higher hardness and strength are developed. These room-temperature properties have been considered adequate for production aircraft. Properties up to 650° F. were also acceptable.

Condition RH 950 – However, with the advent of supersonic aircraft and missiles, and the accompanying problems due to aerodynamic friction and radiant heat from power packs, even higher strengths at temperatures up to 600 and even 800° F. were demanded. To satisfy this requirement a new heat treatment has been recommended which will insure tensile strengths of at least 200,000 psi. (and up to 240,000 psi.) at room temperature. This has been designated as "Condition RH 950". It is developed in parts fabricated from Condition A (soft temper material) by the following schedule of treatments:

1. Heat at 1750° F. ± 15° for 10 min.; air cool.
2. Cool to −100° F. and hold for 8 hr.
3. Heat at 950° F. ± 10° for 60 min.; air cool.

The basis of this new heat treatment is the retention of more carbon in solid solution in the austenite prior to its change into martensite. This contributes to a stronger and harder martensite after the transformation. Upon subsequent precipitation hardening or aging at 950° F. even higher strengths are developed than were obtained by the TH 1050 heat treatment.

To explore the very high strengths possible with this sequence of treatments, five commercial 17-7 PH heats with normal variations in chemical analyses (Table I) were studied. Table II shows the mechanical properties (at room temperature) in the three conditions.

(*Continued on p. 97*)

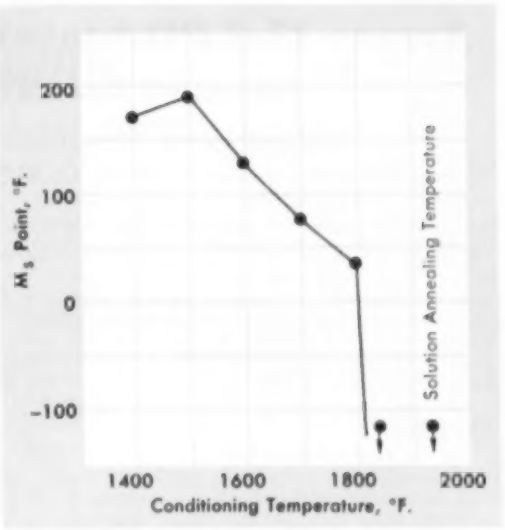


Fig. 1 – Effect of Austenite Conditioning Temperature on Start of Martensite Transformation

Table II – Mechanical Properties* of Armco 17-7 PH 0.050-In. Sheet at 70° F.

Heat	Ultimate	Yield	Elong.	Hardness
	Condition A (as Supplied)			
A	126,000	45,000	39	B-84
B	127,000	50,000	39	B-88
C	128,000	52,000	39	B-85
D	131,000	45,000	38	B-85
E	133,000	45,000	38	B-85
Av.	129,000	47,400	38.6	B-85
	ConditionTH 1050			
A	184,000	163,000	10	C-41
B	185,000	164,000	11	C-40
C	189,000	174,000	10	C-42
D	199,000	190,000	9	C-43
E	209,000	198,000	7	C-44
Av.	193,200	177,800	9.4	C-42
	Condition RH 950			
A	226,000	213,000	8	C-46
B	229,000	217,000	7	C-46
C	230,000	216,000	6	C-46
D	233,000	219,000	7	C-47
E	234,000	218,000	8	C-47
Av.	230,400	216,600	7.2	C-46

*Yield is stress for 0.2% offset; elongation % in 2 in.

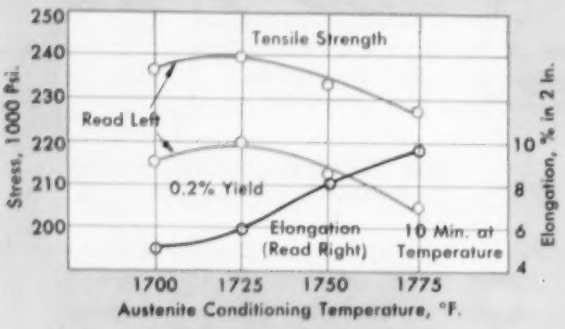
Armco 17-7PH Stainless; Condition RH 950

Effect of Heat Treatment Variables

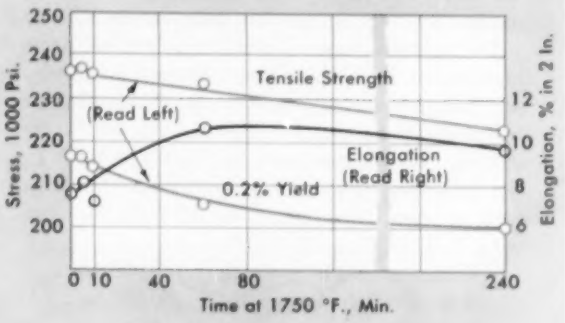
0.050-In. Sheet Tested in Transverse Direction

Nominal composition: C 0.07%, Cr 17%, Ni 7%, Al 1.2%, Mn 0.75%, Si 0.40%

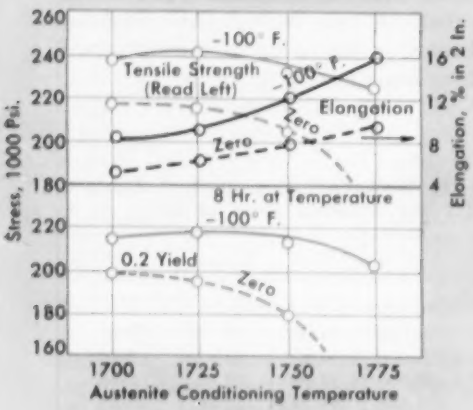
Standard heat treatment: Solution anneal 1 min. at 1950° F., air cool; condition 10 min. at 1750° F., air cool; refrigerate 8 hr. at −100° F.; precipitation harden 60 min. at 950° F., air cool.



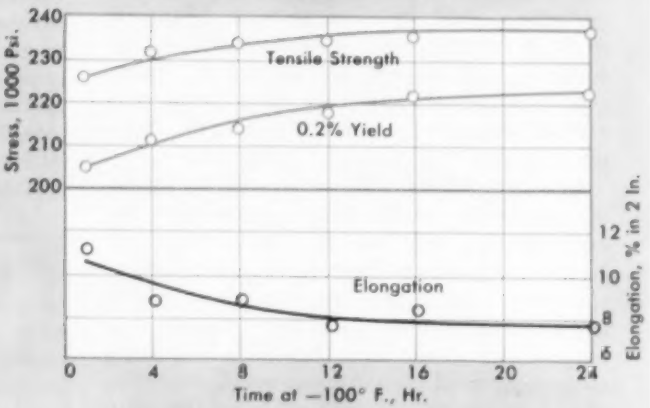
Effect of Variation in Conditioning Temperature



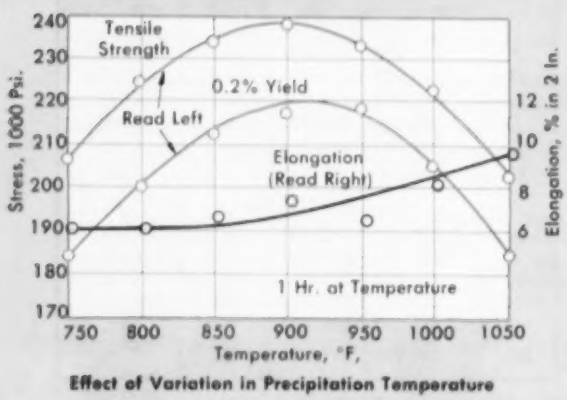
Effect of Time at Preferred Temperature



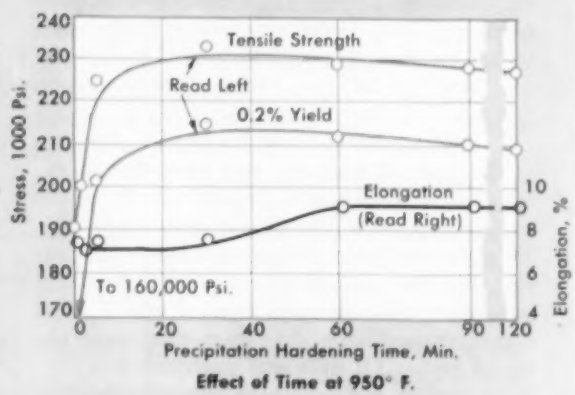
Effect of Refrigerating Temperature



Effect of Refrigeration Time at −100° F.



Effect of Variation in Precipitation Temperature



Effect of Time at 950° F.

Inco high temperature research note:

Nitriding

...and its effects on several heat-resisting alloys

As a constituent of many hot atmospheres that employ air for combustion, nitrogen in molecular form is usually considered substantially inert to a large number of metals and alloys.

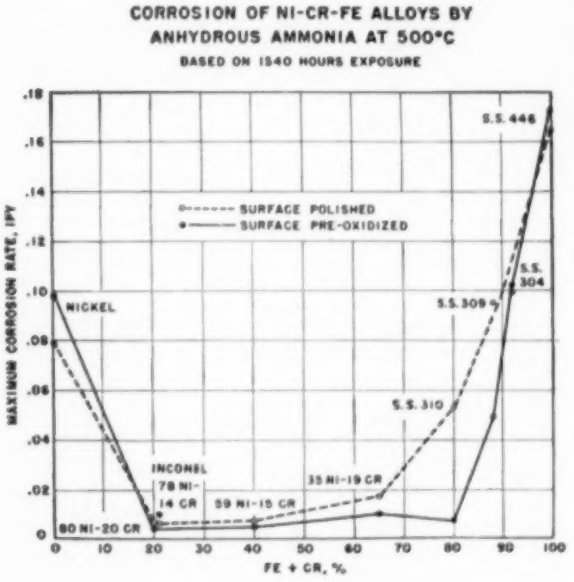
However, in atomic state—for example, as a transient dissociation product of ammonia – nitrogen may react with surfaces of certain metals and distinctly alter their properties. Whether this may be desirable or not, depends on extent and nature of the reaction.

The Problems

Industry heats steels to be intentionally nitrided, in a freshly dissociated ammonia atmosphere to attain the surface hardening that accompanies formation of nitride phases. But the problem is, to avoid nitriding the furnace chamber, dissociator and other accessories . . . a costly and useless consumption of gas. Another problem exists in chemical plants, where equipment handling hot ammonia must resist the absorption of nitrogen. Here nitriding is a form of high temperature corrosion requiring selection of the most resistant alloys for its prevention.

A Postulate

Field experience had shown that alloys high in nickel resist corrosion and embrittlement by nitrogenous atmospheres. However, to evaluate lower nickel alloys



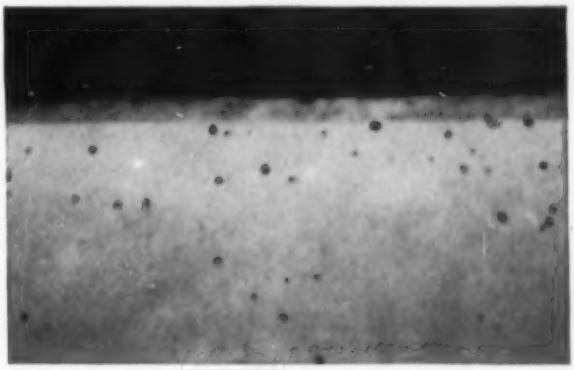
in this type of service, a series of commercial compositions was exposed in a plant ammonia line and the corrosion behavior thereafter compared.

Examination

After 1540 hours' exposure at 500°C, stainless steels having initially a bright surface suffered heavy corrosion that was quantitatively measured by examination of the specimen cross section under the microscope. These measurements were calculated in terms of "inches penetration per year" and the variation in extent of attack with alloy composition is shown in the graph.

When the nickel content is high, as in 80 Ni/20 Cr, 78 Ni/14 Cr (Inconel* nickel-chromium alloy), or 59 Ni/15 Cr, the nitride phases which form are dense and adherent and the corrosion resistance is correspondingly good. Alloys that contain more iron develop porous surface layers and the rate of attack is high. Significantly, apparently some chromium is required to provide corrosion resistance, since under these conditions of exposure, pure nickel is inferior.

An interesting observation from this test is that the stainless steels which were initially heat-treated to form an oxide film were more resistant than specimens with a bright surface.



Material Magnification dark zone nitride rich corrosion layer.

Result of Investigation

Quantitative data obtained from this test in general support past experience that the high nickel compositions are inherently suited for service under nitriding conditions.

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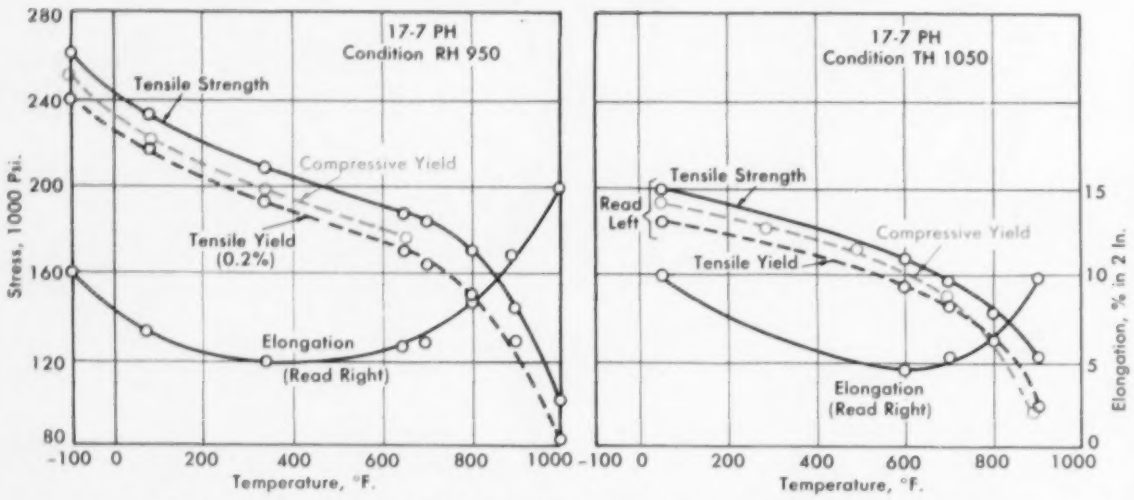
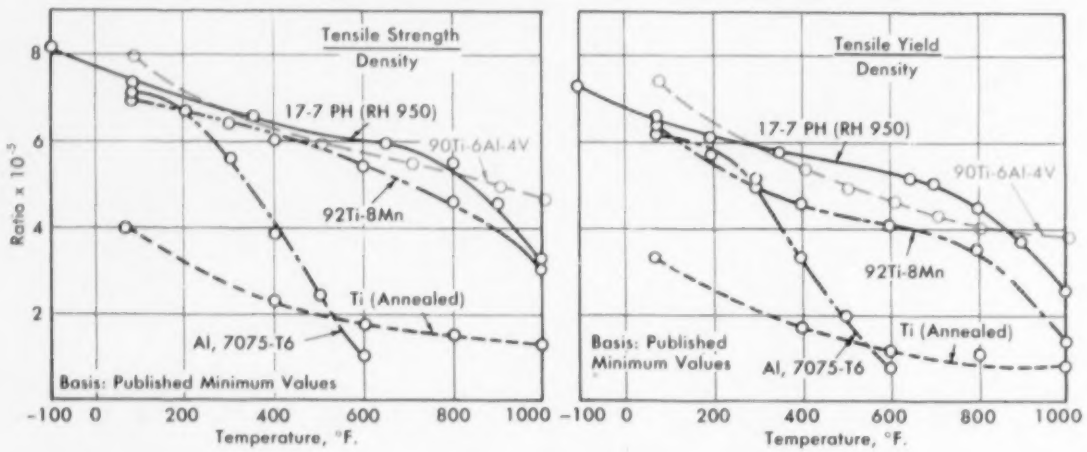
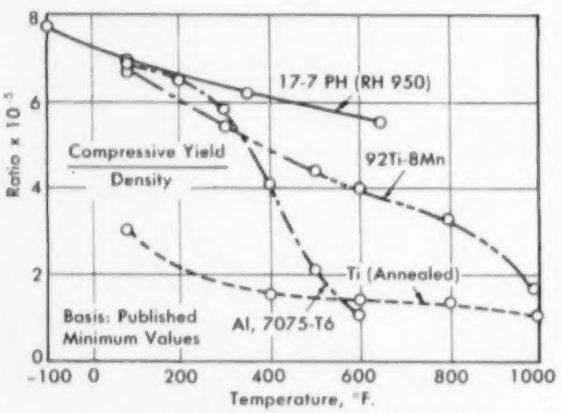
Armco 17-7 PH Stainless

Design Strengths for Elevated Temperature



Typical Short-Time Properties in Tension and Compression, Conditions RH 950 and TH 1050



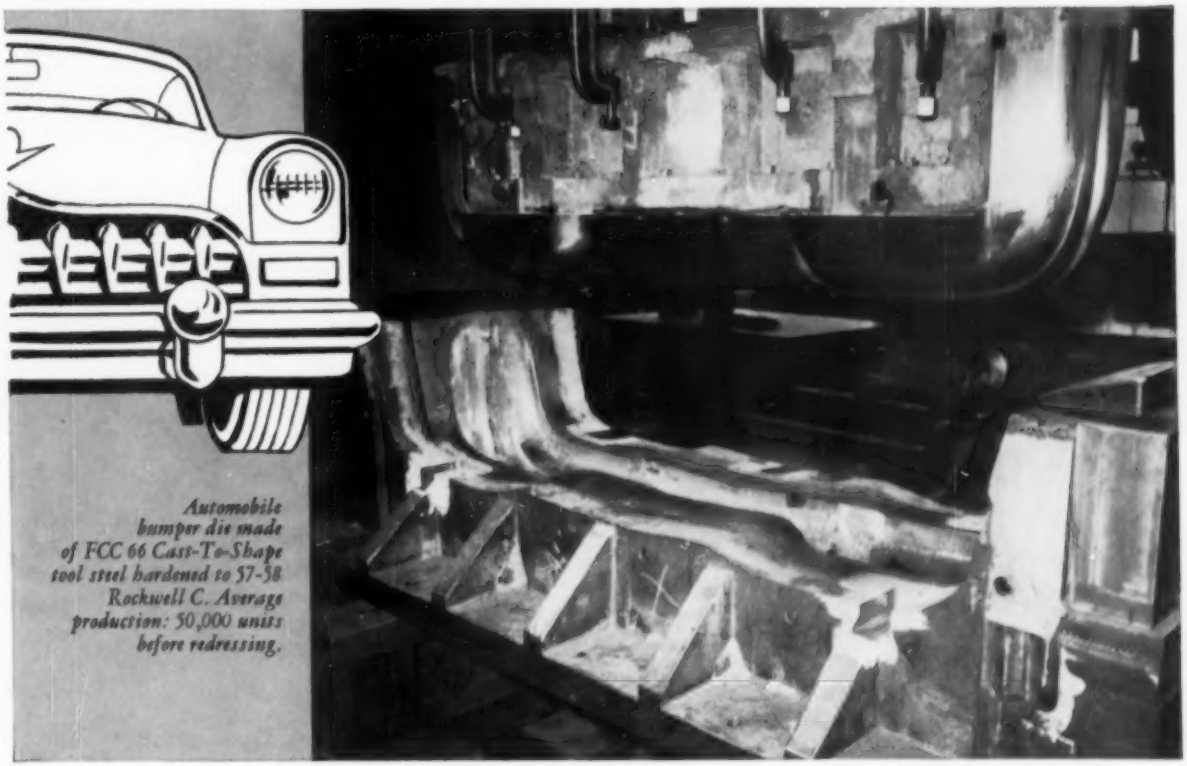


Strength-Weight Ratios of Various Alloys

Physical Properties of 17-7 PH

Property and Units	Condition A	Condition TH 1050	Condition RH 950
Density, Grams per cu.cm.	7.81	7.65	7.66
Lb. per cu.in.	0.282	0.276	0.276
Specific electrical resistance			
Microhm-cm.	81	85	
Magnetic permeability			
At 25 oersteds	1.4 to 3.4	132 to 194	82 to 88
At 50	1.4 to 3.6	120 to 167	113 to 130
At 100	1.4 to 3.5	80 to 99	75 to 87
At 200	1.4 to 3.2	46 to 55	43 to 51
Maximum	1.4 to 3.6	134 to 208	119 to 135
Mean coefficient of thermal expansion; In. per in. per °F. x 10⁶			
0 to 70 °F.			5.7
70 to 200 °F.	8.5	5.6	6.2
70 to 400 °F.	9.0	6.1	6.6
70 to 600° F.	9.5	6.3	6.8
70 to 800 °F.	9.6	6.6	6.9
70 to 900 °F.			7.0
Thermal conductivity, Btu. per sq. ft. per hr. per °F. per in.			
At 300 °F.		117	117 (Est.)
500 °F.		128	128 (Est.)
840 °F.		146	146 (Est.)
900 °F.		146	146 (Est.)

Try this money-saving method that auto-makers use



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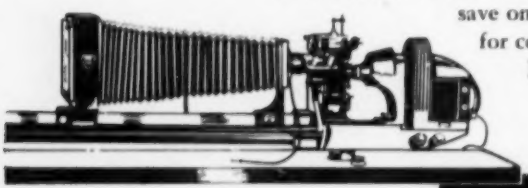

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It is notable that the RH 950 heat treatment increases both the tensile and yield strengths approximately 38,000 psi. on the average over the TH 1050 heat treatment. The elongation values shown for Condition A material – 38 to 39% – are an indication of the excellent forming quality of 17-7 PH stainless steel in the solution annealed state.

Heat Treatment

In fixing the heating conditions for the RH 950 heat treatment, 0.050-in. sheet material from several commercial 17-7 PH heats was selected and extensively studied. The following phases of the heat treating operation were investigated:

1. Initial heat treating temperature and time.
2. Time delay between initial heat treatment and refrigeration.
3. Refrigeration temperature and time.
4. Final hardening temperature and time.

The information is presented in the data sheet on p. 96 so the metallurgical engineer may have a full understanding of the limitations in time and temperature when achieving the best combination of high strength and ductility.

The top left-hand curve sheet shows the effect on final properties of variations in initial heat treating temperatures as they are varied, intentionally, from 1700 to 1775° F. Time at temperature is also a variable, and the top right-hand curve sheet shows the effect of times from 0.5 to 240 min. at 1750° F. These data indicate that the attractively high tensile and yield strengths of 235,000 and 215,000 psi. respectively, with 7% elongation, can be achieved by conditioning the formed sheet at 1750° F. for 10 min. – the first step of the heat treatment which is then followed by refrigerating at −100° F. for 8 hr. and precipitation hardening at 950° F. for 1 hr. These data were obtained on 0.050-in. sheet; for thicker material longer holding times at 1750° F. may be required. Also, for thinner material, longer times at 1750° F. may be employed to improve the tensile elongation (transverse) at a small sacrifice in yield strength.

Table III gives the mechanical properties of annealed 17-7 PH 0.050-in. sheet which has been given only the initial conditioning heat treatment. This is designated as "Condition A-1750" (Condition A plus heating at 1750° F. for 10 min. and air cooling). These properties – especially the low yield strengths – show that sheet in this condition is suitable for mild forming and straightening operations and could be used for aircraft skins. After forming into skins or assembling into wing structures, only refrigeration and final hardening would then be required.

Table III – Mechanical Properties in Condition A-1750

Heat	Ultimate	Yield	Elong.	Hardness
A	139,000	38,000	16	B-82
B	130,000	43,000	20	B-86
C	133,000	43,000	19	B-85
D	150,000	44,000	11	B-84
E	139,000	36,000	17	B-94

Table IV–Properties in Condition R-100

Heat	Ultimate	Yield	Elong.	Hardness
A	175,000	111,000	8	C-38
B	174,000	111,000	10	C-36
C	175,000	111,000	9	C-36
D	171,000	118,000	6	C-38
E	176,000	120,000	16	C-37

Table IV gives the mechanical properties of 17-7 PH after it has gone through the recommended schedule of heat treatments up to and including refrigeration at −100° F. for 8 hr. ("Condition R-100"). These data indicate that mild forming and straightening can also be done in this condition, but with more difficulty than in Condition A-1750. Scale can be removed easily from material in Condition A-1750 by a 10% nitric, 2% hydrofluoric acid pickling operation.

Laboratory tests show that the time delay between the conditioning heat treatment and refrigeration is not critical.

The left center graph in the data sheet, p. 96, compares the properties after refrigeration at zero and at −100° F. Note the higher strengths obtained after the latter. Both of these temperatures are easily obtained. Cold rooms are commonly built in the aircraft industry for refrigeration at zero Fahrenheit. A saturated bath of dry ice (solid CO_2) in alcohol or acetone maintains a temperature of −100 to −109° F. without any control equipment. Commercial equipment is also available for refrigeration at −100° F.

Samples in the A-1750 condition were refrigerated at −100° F. from 2 to 24 hr. Tensile tests on resulting specimens are shown in the right center diagram in the data sheet on p. 96. From such studies a minimum time of 8 hr. was selected for best combination of strength and ductility.

The lower left figure on the same page shows the effect on properties of final hardening temperatures ranging from 750 to 1050° F. (1 hr. at temperature). Maximum tensile and yield strengths are obtained between 850 and 950° F.

Finally, the lower left graph gives the effect of time at 950° F., ½ min. to 2 hr. Although highest tensile and yield strengths are developed after 30 min. at 950° F., maximum tensile ductility is not reached until the sheet is held 60 min. or longer. (All material represented by the two lower figures had received the complete prior cycle of heat treatments.)

Physical Properties

The more important physical properties in Condition A, TH 1050 and RH 950 are given in the table at lower right of the data sheet, p. 96.

Dimensional Change – During heat treating 17-7 PH from Condition A to Condition RH 950 there is an over-all expansion of 0.004 to 0.005 in. per in. in all directions. Dimensional allowances should be made for this increase in the fabrication of parts.

Design Properties

Aircraft engineers base their designs primarily on short-time tension and compression properties at room and elevated temperatures. These are shown in the two top graphs in the data sheet p. 96-B, for Armco 17-7 PH in Conditions RH 950 and TH 1050 for temperatures of −100 to 1000° F. It will be noted that considerably higher strengths are obtained at all temperatures in both tension and compression in Condition RH 950 than in Condition TH 1050.

The other figures in that data sheet compare strength-weight of 17-7 PH, Condition RH 950, with other aircraft structural sheet materials used or recommended for severe-temperature duty. This comparison is made for short-time tensile strength, short-time tensile yield strength, and short-time compression yield strength, respectively, over the range −100 to +1000° F. All data have been proportioned to conform to published minimum values at room temperature. For 17-7 PH, Condition RH 950, 200,000-psi. tensile strength and 180,000-psi. 0.2% offset yield strength were used as the basis.

It can be easily seen that 17-7 PH in Condition RH 950 should be considered along with the strongest sheet materials currently available, when figured per unit of weight over the entire temperature range.

Additional data on other mechanical properties have been developed which are of special interest to the aircraft industry:

Young's modulus of elasticity was determined by a sonic method over the temperature range of 75 to 1000° F. It is 29,000,000 psi. at room temperature, 27,000,000 at 500° F., and 23,000,000 psi. at 1000° F. This parallels the normal decrease in modulus of the steels and ferrous alloys over this temperature range.

Tension tests of notched samples were made at 75 and 350° F. to determine the notch sensitivity of 17-7 PH, Condition RH 950. Theoretical stress concentration factors of 3.4 and 1.9 were obtained by opening 1/16-in. and ¼-in. diameter holes to the edge of the test specimen. The tensile strength, under these conditions, was respectively 7% and 14% greater than the unnotched values. These results indicate that the product is relatively free of notch sensitivity.

Bearing tests were run on 0.050-in. thick sheet, using a pin ¾ in. in diameter and an edge distance of two diameters. The bearing yield strength at 2% deformation of the ¾-in. hole was between 365,000 and 392,000 psi. at room temperature. The ultimate bearing strength was in the range of 455,000 to 470,000 psi. This is approximately twice the tensile strength.

17-7 PH in Condition TH 1050, with tensile strength of the order of 190,000 psi., has acceptable impact strength. Equally good impact strengths were obtained in Condition RH 950 with higher tensile – about 220,000 psi.

17-7 PH is readily welded by any of the conventional methods. Preliminary data on inert-gas tungsten-arc welded specimens indicate that joint efficiencies of at least 85 to 90% can be expected in Condition RH 950. These test pieces were welded while in Condition A and were subsequently heat treated to Condition RH 950.

17-7 PH stainless steel has been widely used in honeycomb structures. Since they must be heat treated in either inert or reducing atmosphere (free of nitrogen and carbon), modifications of the standard TH 1050 heat treatment have been used. Brazed honeycomb structures can now be made with the RH 950 treatment and achieve higher strengths by combining the brazing operation (through proper selection of brazing alloy) with the initial heat treatment at 1750° F. This must be followed, of course, by subsequent refrigeration and hardening. Greater savings in weight are foreseen by the use of honeycomb structures, heat treated to the high strength level of Condition RH 950.

A number of aircraft engineers who have reviewed these data agree that 17-7 PH in Condition RH 950, because of its ease of fabrication, simplicity of heat treatment, and attractively high strength, is a material eminently suitable for supersonic aircraft and missiles.

Control of Controlled Atmospheres

*By D. J. SCHWALM**

Measurement of the carburizing potential of furnace atmospheres is more accurate if infrared analysis of carbon dioxide is used instead of dew point determinations. (J 2, S 11)

THE THEORY which governs the control of the carburizing or decarburizing potential of a furnace atmosphere has been known for many years but its proper application is still a major source of controversy. Chemical equilibrium principles indicate that in the atmospheres containing carbon monoxide, carbon dioxide, hydrogen and water vapor, the ratios between the gases present are constant at any specific temperature and vary only with temperature. If the amount of two or more of the gases present is known then the amount of the others can be calculated to determine the carburizing potential of the atmosphere.

The theory is sound but there are obvious pitfalls. For example, the constant relationship between the various gases is only exact under equilibrium conditions, which are seldom reached in industrial heat treating furnaces except in small batch furnaces held for long times at constant temperature. If each constituent of the atmosphere could be measured continuously, the equilibrium problem would be solved, but obviously such control for production operations would be extremely costly. Another problem is sampling because the gas analyzed must be representative of the atmosphere reacting with the steel or the calculation of carburizing potential will be meaningless.

In 1934 carburizing potential control by analysis of furnace atmosphere was applied for the first time in production. The installation was a Holcroft & Co. furnace in the Dodge automotive plant for clean hardening and carbon restoration of axle shafts. The atmosphere was a rich, dry gas whose composition was approximately 16% CO, 2% CO_2, 22% H_2, 7% CH_4, balance nitrogen and its dew point was below 40° F.

The following year, a gas generator was developed which produced an atmosphere with approximately 21% CO, 16% H_2 and balance nitrogen. The amount of hydrocarbon addition necessary to maintain a carburizing potential for surface carbon content greater than 0.80% was reduced so that sooting was no longer excessive. The ease and reliability of the process was improved and the attack on alloy parts reduced. In 1936 ammonia was also added to the gas to produce an atmosphere for what is now known as the carbo-nitriding process.

This generator was eventually replaced by the more convenient and economical nickel catalyst generator which produces a gas whose composition is about 20% CO, 40% H_2 and 40% N_2 with a dew point between −5 and 50° F. Although several disadvantages are apparent when operating with this atmosphere, it is still being used as

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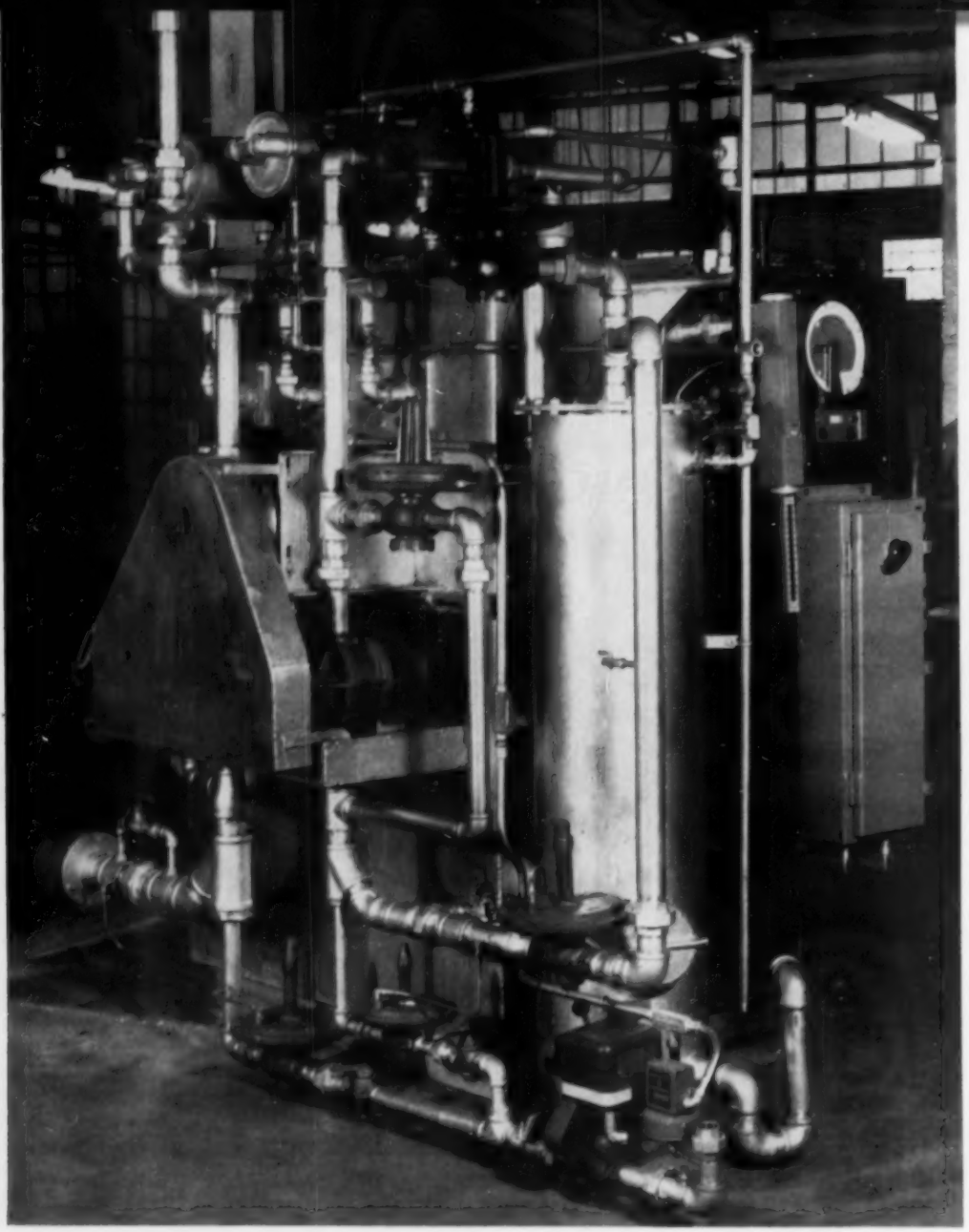


Fig. 1 – Lo-Dew Atmosphere Generator

a carrier gas for gas carburizing, clean hardening and carbo-nitriding.

Among the more obvious difficulties is the problem of maintaining constant output analysis. The reaction in the generator is a combination of an exothermic reaction in which the available air combines with the gas and an endothermic reaction in which the initial products of combustion react with the remaining gas. At rated capacity it is difficult to maintain constant output analysis over the entire flow range so most such generators are set up to give a peak capacity of only 70 to 80% rated capacity. An even greater problem is the fact that variation in analysis of the principal constituents, hydrogen, carbon monoxide and nitrogen, is not possible. When natural gas is used, the composition is automatically 20% CO, 40% H_2 and 40% N_2, a mixture which is more explosive than the 16% H_2 and 21% CO combination produced by earlier generators and which is not as suitable for clean hardening and carbo-nitriding operations carried on at temperatures below 1700° F.

For these reasons we developed the Lo-Dew gas generator shown in Fig. 1. In it, a controlled

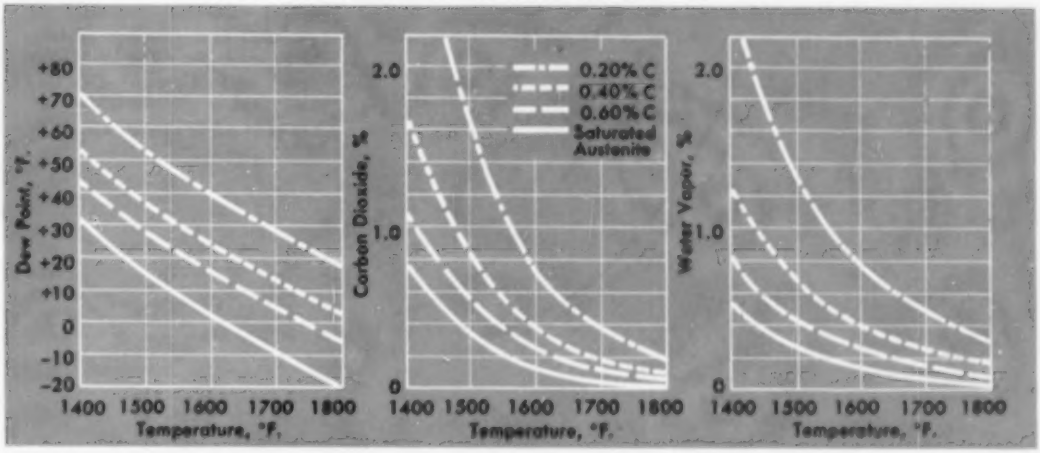


Fig. 2 – Relationship Between Carbon Potential and Content of Carbon Dioxide or Water Vapor in an Atmosphere Containing 17% Carbon Monoxide

mixture of gas and air is completely burned in a closed chamber. The products of combustion are cooled by passing through a spray tower, and a controlled amount of hydrocarbon is added to part of the cooled gas. This mixture is passed over a catalyst heated by the primary combination and the endothermic reaction produces a gas of approximately 17% CO, 20% H_2 and 63% N_2 with dew points ranging down to at least – 75°F. – about the limit of accurate measurement.

Unlike the earlier endothermic generators, this unit can produce atmospheres with a wide range of compositions. By changing the amount of hydrocarbon added to the combustion products, the endothermic reaction can be made to produce CO_2 up to about 12%, CO up to 17%, H_2 up to 20% and dew points from −75 to 70° F.

In addition to the furnace atmosphere, the generator also produces an exothermic gas at a second outlet. This gas is a byproduct of the primary heating reaction and corresponds to the wasted vent gases from the earlier endothermic generators. It is continuously available and has a constant analysis because it is formed from a carefully controlled mixture. It can be used for any heat treating process requiring a lean exothermic atmosphere. Mixing the two gases produced by the generator can give a resultant atmosphere anywhere between lean exothermic and rich endothermic. It is also possible to use the exothermic gas or the entire output of the generator minus the hydrocarbon addition to purge furnaces containing valuable stock for emergency repair shutdowns without any possibility of explosion.

The cost of the atmosphere per cubic foot produced is low because none of the hydrocarbon fuel used in the generator need be wasted. None of the fuel is used exclusively for heating as in the other kinds of endothermic generators.

The extremely low dew points which can be obtained with this equipment are used only for special applications. For conventional use of the gas as a diluent for carburizing or carbo-nitriding, the dew point is normally held in the range of about −10 to 10° F. This range is so far above the lower operating limits of the generator that continuous operation at rated capacity with virtually no sooting is easily maintained. If burnout is necessary, the hydrocarbon addition for the secondary reaction is reduced or stopped momentarily. This allows a lean exothermic gas to pass over the catalyst and react endothermically with any carbon deposited. Because this reaction is endothermic there is no danger of overheating and damaging the retort.

The Lo-Dew generator produces a gas with not only a lower dew point but also a much smaller amount of the combustible components, hydrogen and carbon monoxide. Lowering these two constituents in a furnace atmosphere alters the equilibrium relationship between the atmosphere and the carbon content of the steel processed since the carburizing or decarburizing potential of an atmosphere is governed by the composition balance. Equilibrium relationships for the Lo-Dew generator gas are shown in Fig. 2. It is important when using curves of this type to bear in mind that they are correct only when the assumed constants used to develop the curves

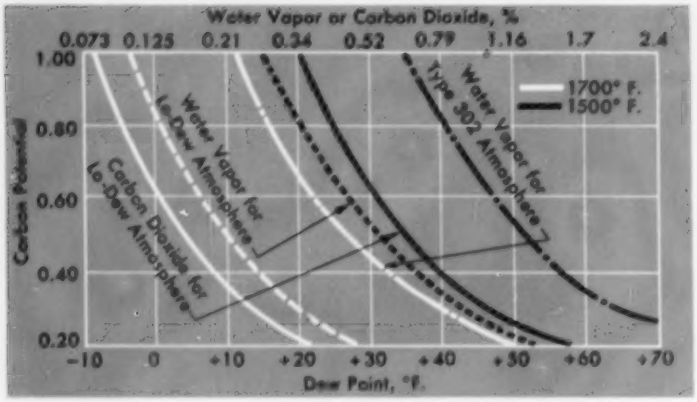


Fig. 3 — Carbon Potential of Type 302 and Lo-Dew Atmospheres as a Function of Water Vapor and Carbon Dioxide. Black curves are for 1500° F. Curves in white are for 1700° F.

equal the actual values in the atmosphere.

The major question in atmosphere heat treating is how to measure and control the gases used. The most direct method is by Orsat analysis. This has been very satisfactory but is a time-consuming operation and requires highly trained personnel. For this reason many atmosphere installations are operated with measurement of only one of the four important gas components. The other three are assumed to be constant and control is attempted on this basis. At best, this method is but a rough estimate of the atmospheric conditions inside the furnace and only serves as a check to show any drastic changes in furnace conditions since the last successful stock processing.

The two constituents most commonly measured are carbon dioxide and water vapor or dew point with the preference favoring the latter because of its easy measurement. The preference for dew point measurement has increased with the development of automatic measuring equipment, primarily because of cost, and until recently because no other satisfactory equipment was available. This situation has now changed, however, with the introduction of infrared analyzers for easy, accurate measurement of diatomic gases. The problem is no longer "What can we measure?" but "What should we measure?"

For an endothermic generator gas with no hydrocarbon addition, the decision must be either carbon dioxide or water vapor if only one analyzer is to be used. The first factor to consider when deciding between the two is which more correctly represents carbon potential. Either may be used successfully because their relationship to carbon potential is almost identical, as shown in Fig. 3. The next consideration is which can be measured more accurately and reliably by present-day equipment.

The error which can be expected with conventional dew point measuring equipment is reported to be about plus or minus 2½° F. The error in measurement of carbon dioxide with an infrared analyzer is about plus or minus 0.005% in the range found in carburizing atmospheres. At 1700° F. with either the Lo-Dew or the Type 302 gas at a carburizing potential of 0.95% carbon, variation of 5° F. in dew point is equivalent to about 0.25% carbon whereas a variation of 0.01% CO_2 is equivalent to less that 0.10% carbon.

If dew point is used for control of the Type 302 gas, another problem arises when the furnace temperature is changed. Conventional dew point equipment requires a different ambient temperature range control for furnace temperatures of 1700 and 1500° F. If carbon dioxide is the control gas, the normal scale of infrared equipment is good for such a variation in temperature. When hydrocarbon is added to endothermic gas another possibility arises. The carbon potential of such an atmosphere can be controlled by either of the above gases or by measurement of CH_4.

The final decision as to which gas or how many gases should be measured and controlled can only be based on the particular problems pertaining to an individual installation. Much research effort is being directed to the perfection of some method of actually measuring carbon potential but as yet we are not ready to insist on any specific equipment although we are willing to make recommendations as to what should be done on individual applications. If the equipment is purchased and operated on the basis that it is not actually controlling but only helping to maintain an atmosphere of relatively constant conditions it can give very satisfactory results.

Development of Arc-Cast Molybdenum

*By ALVIN J. HERZIG**

Molybdenum-base alloys have become commercially available after a long and often discouraging program of development of the necessary equipment and techniques. (C 25, Mo)

When William P. Woodside retired from research in 1943, I believe that he thought his primary job was done and that the organization he had founded would proceed without his guidance along the line he would wish to see it travel. We believe we have made progress since that time in several areas of effort, among the most interesting being our program on arc-cast molybdenum. We must acknowledge that the Woodside philosophy of investigation contributed a good deal to such progress as we have made.

The possibility that molybdenum had a metallurgical future beyond the realm of an alloying element in iron-base alloys was by no means an original concept in our organization. The processes of powder metallurgy developed many years before, and the advancement of certain nickel-base alloys which had a fairly high content of molybdenum, provided positive evidence that a new approach to the field of molybdenum-rich materials might be technically and commercially attractive. It is not an easy matter to recollect the complete chain of ideas which grew into what we now call the arc-cast molybdenum program. Even in the earlier years, Mr. Woodside had encouraged what he called metallurgical slumming.

Our first investigations outside the ferrous field were with copper, nickel and cobalt-base alloys containing relatively large percentages of molybdenum. In the study of dispersion of molybdenum in copper, we saw molybdenum metal segregates and this was the first time any of our staff had observed a consolidation of molybdenum by a process other than powder metallurgy. It must be admitted, however, that in looking back, we cannot establish a conscious connection between these experiments and the beginning of our arc-cast melting program other than the fact that the 14th on a suggested list of projects prepared in 1937 was the subject "preparation of large bodies of molybdenum". The high melting point of molybdenum and the special atmospheres required when melting it appeared to be formidable obstacles.

As a result of the work during the early war years on the production of chromium-base alloys, we obtained a good deal of experience with temperatures higher than those ordinarily employed in ferrous research, with the behavior of available refractories and with the attainment and maintenance of reasonably good vacuums in spaces large enough to conduct metallurgical operations. Perhaps of even greater significance, the chromium-base alloy program established in our staff a conviction that the pure metallic state was a ductile state. It now makes little difference whether this conviction is basically true or false. Its acceptance as truth provided the incentive to continue when during the early months of research, ingot after ingot, presumably free of deleterious impurities, fell apart in the first forg-

*President, Climax Molybdenum Co. of Michigan, Detroit. This is the third and final article of a series based on the 13th annual Woodside Lecture presented to the Detroit Chapter ASM.

Fig. 1 – Fractograph of Cast Molybdenum Reveals Oxide Film Which Causes Embrittlement

ing operations. In 1943, when we were invited to participate in a program to develop and extend the processes of powder metallurgy to attain larger bodies of molybdenum, we requested permission to work on the problem of consolidating large bodies of molybdenum by processes other than powder metallurgy. This request was granted. The program has been continuous since that date on an ever-expanding basis.

The following broad specifications were developed for the opening experiments:

1. Melting temperature would be attained by an alternating current arc in vacuum using two horizontal consumable molybdenum electrodes.
2. The electrodes would be sintered molybdenum rods.
3. Arc spacing would be controlled manually.
4. Metal from the arc would be allowed to drop on a sintered molybdenum block to solidify.

The Brittleness Problem

A series of experiments on this pattern yielded valuable information.

The techniques were satisfactory; the alternating current arc in vacuum not only supplied power to melt but provided a substantial and indeed an essential degree of superheat, since we intended to produce ingots, not metal shot. Even in this crude setup, the arc was relatively stable and could be maintained by manual control. Unfortunately the product was not as good as we expected. The porosity of the metal buttons was the first evidence that a gas problem would be involved. We presumed the gas was hydrogen from the sintered electrodes. In addition, the buttons were extremely brittle.

There were conferences and more experiments. The apparatus was changed to a vertical position. One sintered electrode was eliminated by using the bottom block as the second electrode. A copper block was eventually substituted for the molybdenum bottom piece. The gases evolved during melting were analyzed and were found to consist chiefly of carbon monoxide and nitrogen rather than hydrogen. The product was still extremely brittle.

However, as we gained experience with the apparatus, the product was beginning to clean up both externally and structurally, and 1-in. diameter buttons could be produced regularly, although they could not be deformed appreciably at any temperature. Degassing the electrodes prior to melting gave inconclusive results. Chemical analyses and metallographic examinations did not detect the contaminants we were certain must be present. We continued to strive for higher purity without knowing what impurities we wanted to remove. Finally came a ray of hope. An occasional slug exhibited some hot plasticity in that a blow with a ball-peen hammer indented rather than fractured it. Chemical analyses and metallographic examinations still failed to characterize a good slug and a bad slug. Eventually, the fortuitous examination of a fractured surface of a brittle slug was made at high magnification by Gordon C. Woodside. Pink to purple plates of a constituent on the fracture faces of the totally brittle material were

Fig. 2 – Deoxidation of Molybdenum With Carbon Produces Feather-Like Structure in Fractograph

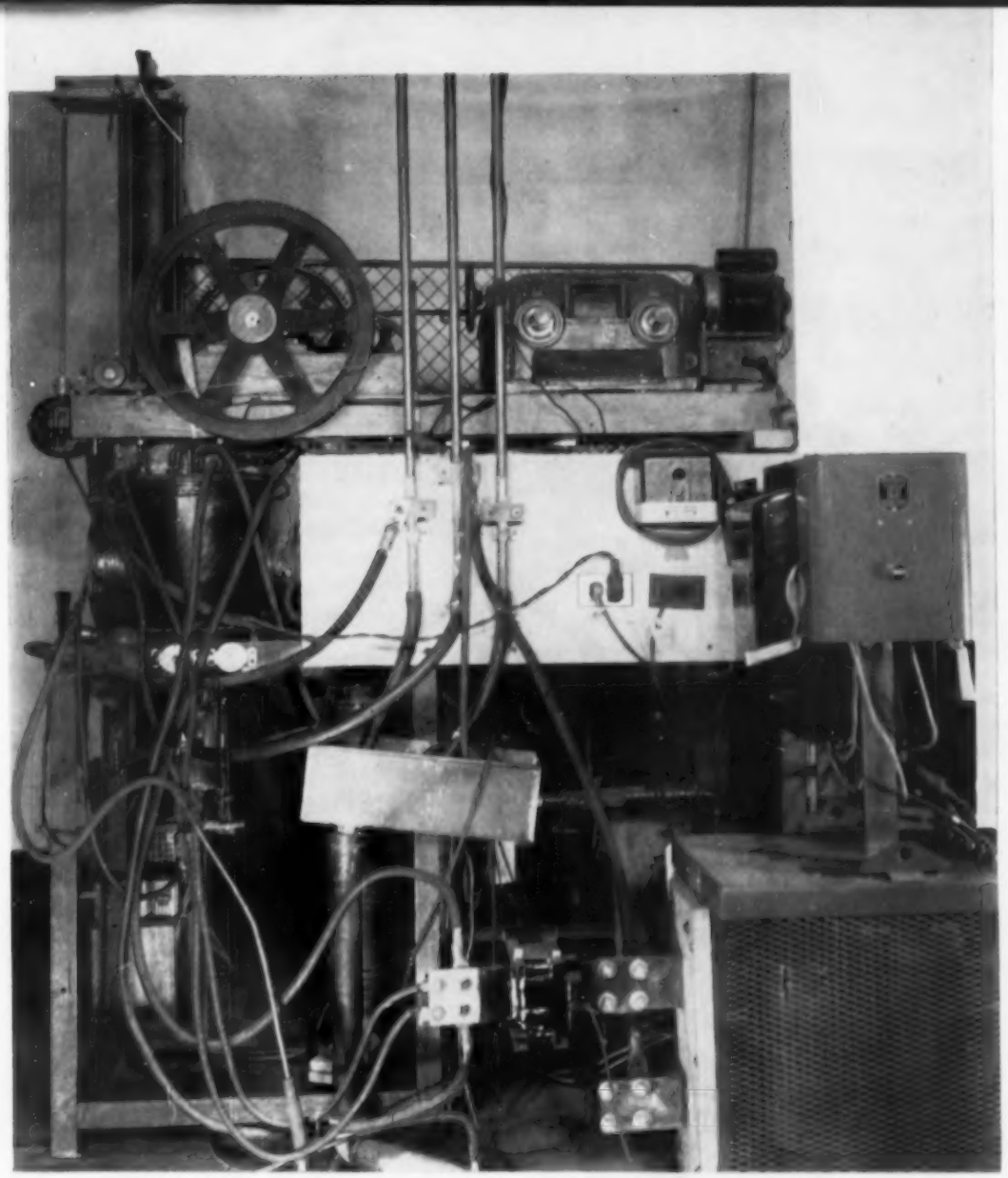


Fig. 3 – First Successful Equipment Used to Melt Molybdenum Ingots in Commercial Sizes

observed, as shown by the dark areas in Fig. 1.

The sheets of oxide are so thin that they escape detection in a metallographic cross section mechanically polished. In recent years, we have developed electropolishing methods which would reveal this amount of oxide, although the oxygen content in this specimen is less than 0.01%. At first we stumbled briefly on the possibility that the colored constituent was a film of copper produced by contamination from the bottom copper block. However, we soon perfected the technique of high-magnification fractography and on the basis of many examinations and a lot of argument, decided that the constituent must be an oxide of molybdenum.

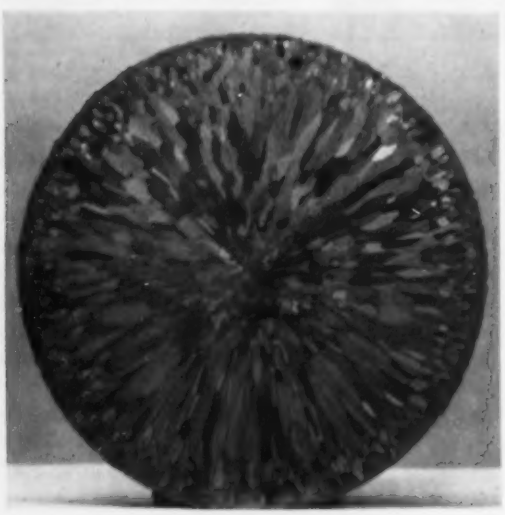
The necessity for better deoxidation was indicated, so we drilled holes at ½-in. intervals in the electrodes and filled them with graphite. The slug produced from such electrodes withstood an encouraging amount of hot deformation and the porosity was gone – so were the plates of oxide. Feathery constituents replaced the oxide at the grain boundaries and these feathers, shown in Fig. 2, are a typical manifestation of carbide on the fracture facet of a sample from a molybdenum casting. Carbide in a polished metallographic cross section appears in the more conventional form familiar to metallographers.

Casting a 2-in. ingot in a water-cooled copper mold was the next objective. The first ingots were only a few inches long but finally an ingot 10 in. long, sound and forgeable, was obtained.

A forged and annealed bar from this ingot showed approximately 50% elongation in a 0.505-in. test section. This convinced us that arc-cast molybdenum was metallurgically feasible and could give us soundness and ductility not achieved at that time by powder metallurgy. The loose ends of quantitative refinement were left dangling as we went on to the problem of obtaining a more suitable electrode. The objective was to form the electrode from powder within the vacuum container at a variable but controllable rate. We wanted to add the carbon for deoxidation prior to compacting and were reasonably certain alloys could be added in the same way. We soon found that this operation required a unique mechanism and several designs were proposed.

The first successful device employed a crank and connecting rod to drive the compacting piston and a cylindrical collet die actuated by springs which resisted lateral pressure while compacting an electrode section, but released the compact for downward movement of the electrode at the end of the stroke. The machine was a monstrosity, as shown in Fig. 3, but it melted 3-in. diameter ingots, 24 in. long. The billets were the first to be rolled on a commercial mill and yielded the first significant quantities of bar stock for determination of physical properties. In the meantime, we had not only obtained confirmation by X-ray analysis that the intergranular phase of inadequately deoxidized ingots was indeed molybdenum dioxide, but also that too high a residual carbon content could detract from the hot plasticity of smaller section sizes.

Fig. 4 — Coarse Grain Structure of 6-in. Diameter Ingots. Approximately half size



A larger machine went into operation late in 1946 and produced 6-in. diameter ingots weighing up to 350 lb. It is still in operation at the laboratory on experimental operations. The increase in ingot size introduced new problems in fabrication, especially at the ingot cogging stage. The yield was only slightly better than prohibitive but we concluded that it was necessary to go on. Although there was a decided lull in interest in molybdenum and its alloys for defense purposes, a new interest in unusual materials had been created in the industrial field. We hoped that we might remove molybdenum from the category of exotic materials and satisfy the growing demand for ultra high-temperature strength. Some applications were suggested and this was enough to carry us through the dismal and unsuccessful period of developing a feasible hammer-cogging practice for the coarse-grained ingots. The extremely coarse structure of the 6-in. ingots is apparent in Fig. 4.

In retrospect, it seems we went out on a limb. If we were going to come anywhere near a commercial cost, we had to melt still larger ingots and yet it was almost certain that larger ingots would complicate the operation of breaking down the coarse ingot structure. Nevertheless, in the fall of 1949, we received approval to build a melting unit capable of melting ingots up to 12 in. diameter and 4 ft. long. We proposed to solve the cogging problem by press forging or by extrusion.

This unit, shown in Fig. 5, produced a sound 1000-lb. ingot about mid-January, 1951. The deoxidation in the new machine was comparable to that in the previous machine but the recovery from hammer-cogged and pressed-forged ingots remained disappointingly low. Then came word of the Sejournet extrusion process. Ingot sections flown to France were successfully reduced by extrusion. A repeat program revealed that this extrusion practice was much better suited to the tender cast structure than press forging or hammer cogging.

The extrusion process is still the most feasible for breaking down arc-cast molybdenum ingots. The macrostructure as extruded is shown in Fig. 6. Turned ingot sections 8¾ in. in diameter and weighing 400 lb. have been extruded success-

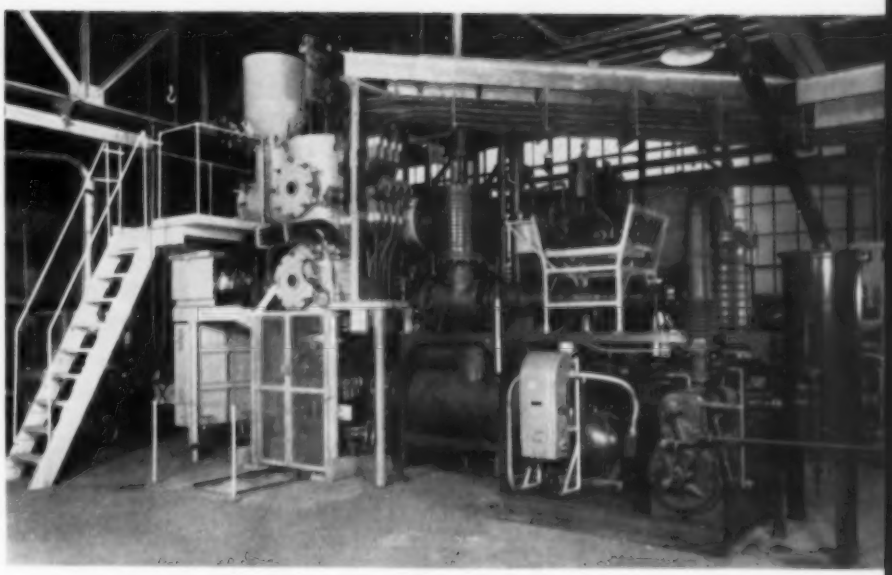


Fig. 5 – Melting Equipment Installed in 1950 to Produce 12-In. Molybdenum Ingots

fully to 6-in. diameter billets. The usual practice, however, is to supply turned ingot sections 6⅝ in. in diameter and 20 in. long for extrusion to 3½ to 4¼-in. diameter billets.

The principal problems encountered in rolling extruded billets were the requirement of frequent reheating, the problems of slipperiness and of visibility due to the continuous volatilization of molybdenum trioxide and the unusual stiffness of the material. Semifinished arc-cast molybdenum products of adequate quality for pilot development programs became available about the middle of 1951 in a variety of round bar sizes, sheet bar and sheet.

Meeting Base-Metal Requirements

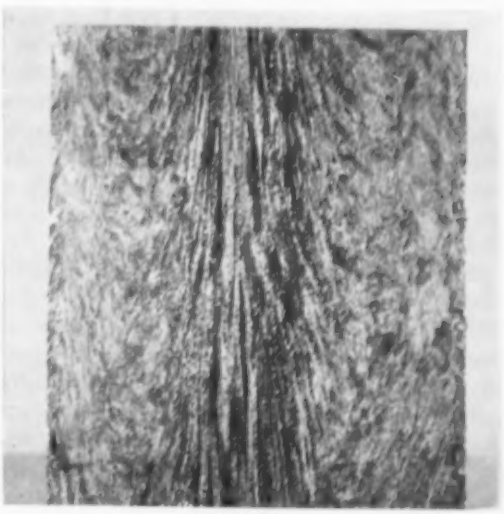
As soon as it appeared feasible to produce larger bodies of molybdenum than those which were available from the processes of powder metallurgy and which could be fabricated to the shapes required for commercial applications, it appeared desirable to take a still broader view of the entire development. No one doubted that the largest ultimate use of arc-cast molybdenum would be found in the alloys for which molybdenum served as a base metal rather than in the pure molybdenum metal.

The list of elements which have achieved the role of alloy base metals in all metallurgical history is not particularly long. The metals of antiquity would be copper, iron, tin, lead and a few of the noble metals. The modern metals on the list would be nickel, zinc, aluminum, cobalt and magnesium. Intensive laboratory work at the present time on new alloy base metals centers around titanium, molybdenum, chromium, zirconium and columbium.

To become a base metal for an alloy system, the metal must meet certain requirements. First, it must be available in quantities commensurate with the proposed usage. Second, it must be amenable to the developed methods of compounding its alloys. Third, the properties of its alloys must meet some new engineering requirements not fulfilled by existing materials. Fourth, the alloys must be commercially useful.

Our decision to undertake a full program on molybdenum-base alloys necessitated a further expansion of research and development facilities and when the first binary molybdenum alloys produced with tungsten and vanadium exhibited superior stress-rupture strength, the Office of Naval Research sought to speed up the development by sponsoring research on molybdenum-

Fig. 6 – Macrostructure of an Extruded Molybdenum Billet



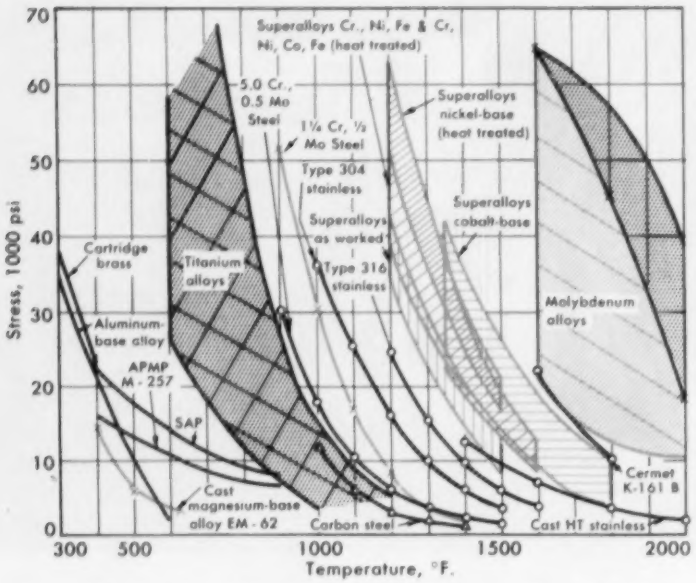


Fig. 7 – Stress-Rupture Strength of Various Materials

base alloy systems. One of these sponsored programs began in our laboratory in 1950. The program continues at this time toward the establishment of the general characteristics of the system of molybdenum-base alloys.

The metals iron, copper, tin, lead, aluminum, zinc, chromium, magnesium and nickel are household words. Even rarer metals, such as cobalt, tungsten and the noble metals, are well known to the public at large. Molybdenum, on the other hand, is a relatively unknown word. Although molybdenum was filling a responsible position in the field of alloy steels as long as 25 years ago and although it is the only alloying element commonly applied today in the field of ferrous metallurgy whose principal supply is in the United States, the element has never achieved particular notice at the popular level. It is quite probable that this lack of public knowledge is due to the fact that molybdenum has no use which parallels the use of tin in cans, copper in wire, lead in pipe and batteries, aluminum in foil and chromium and nickel in plate.

Built around a metal with a melting point of approximately 4750° F. and an elastic modulus of 47 million psi., a lowest temperature of recrystallization of 1650° F., a low coefficient of thermal expansion, high thermal conductivity and an extraordinarily low gas content, arc-cast molybdenum-base alloys are characterized primarily by superior strength and stiffness at elevated temperatures and by excellent resistance to thermal shock. Six years of development effort have indicated that molybdenum-base alloys will soon be added to the list of materials of construction and will extend the use of the metallic state to a temperature range beyond the realm of the older classic alloys. Figure 7 shows the stress-rupture strength of the system of molybdenum-base alloys already explored compared with the stress-rupture strengths of other established or proposed refractory materials. The area dotted in color shows the stress-rupture strengths obtained in the presently known binary alloys. Even in the lower portion of this area, the strengths compare favorably with the cermets. The upper portion in black shows the strengths of the ternary alloys on which exploration has just been undertaken.

Applications

Such characteristics suggest several important applications in the field of the modern turbine engine, the ram-jet and the rocket-propelled devices. They indicate applicability to special hot working tools and to machine tool elements and airframe applications requiring materials of high modulus. The latter applications would be room-temperature uses of the materials now becoming commercially available.

Specific development programs are being conducted in industry on such items as incandescent and fluorescent lamps, electronic tube elements, wire, shields and baffles for electric furnaces, electric glass-melting furnace electrodes and stirring rods, electrical contacts, heat treating furnace rollers and parts, piercing points for seamless tubing, hot work and die-casting dies, boring bars and spindles, turbine blades, heat exchangers for nuclear reactors, flame holders, guide vanes and superior abrasion resistant tools. The alloys also present new possibilities by virtue of their special resistance to attack by certain chemical environments. The principal problems remaining in these areas of specific applications deal with the fabrication in forming of parts and with the protection against oxidation where the applications involve an oxidizing environment. The formability is indicated by the flow-

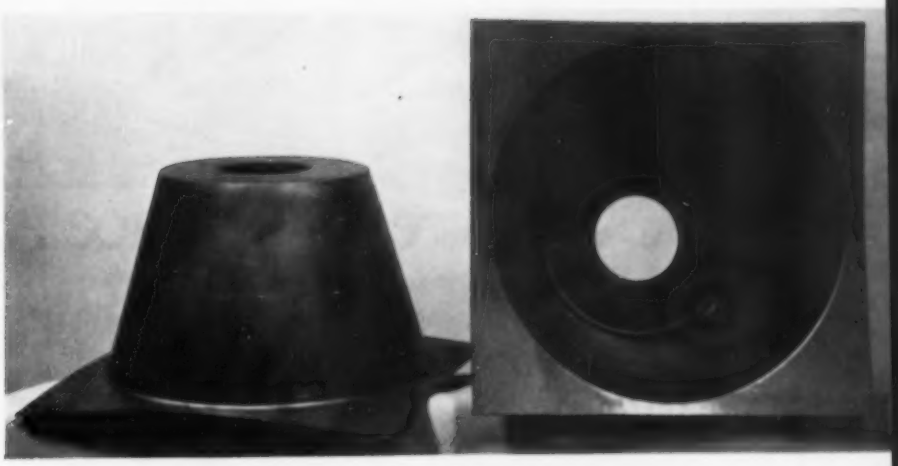


Fig. 8 – Flow-Turned Shape Made From Molybdenum Sheet

turned section of 1/16-in. molybdenum sheet shown in Fig. 8. The same section has also been formed with 3/16-in. plate.

Arc-cast molybdenum machines well if provision is made for the abrasiveness of even the pure metal. Highly specialized techniques are required for successful welding and, like the problems of oxidation resistance, welding practices must be precisely adapted to the specific requirement of a given application. An additional source of supply of the products will soon be in operation and the newest supplier is also undertaking the development of further improvement in the low-temperature ductility of the products through establishment of what is called "closed circuit fabrication". This system provides the ideal environment for the material from the time the powder is charged to the melting machine until the time the semifinished products have been manufactured.

Conclusions

Molybdenum is abundant in the western hemisphere, and the evolution of molybdenum and molybdenum-base alloys as engineering materials involves the development of four major aspects of the over-all problem. These aspects are: (*a*) the establishment of the properties obtainable in the new materials, (*b*) the development of commercial methods of producing and fabricating the new materials, (*c*) the discovery of methods for protecting the materials from oxidation at elevated temperatures, and (*d*) the design of machines and equipment to use the new materials in our expanding technology.

The status of arc-cast molybdenum and its alloys on these four counts is as follows:

1. The metallurgical foundation for the development of the new series of metallic alloys is virtually assured. Wrought alloys amenable to most of the current fabrication processes and having characteristics at elevated temperatures well beyond those of the present so-called "superalloys" are being produced.

2. Pilot operations over a period of four years have demonstrated that the commercial production of molybdenum and its alloys by the arc-casting process is feasible. For large section sizes and for material having special requirements such as low gas content, molybdenum produced by the arc-cast process has advantages over the materials produced by powder metallurgy.

3. The difficult problem of protecting molybdenum from oxidation has received the attention of many well-qualified investigators, both at the fundamental and the practical levels. The question of protecting molybdenum has already been reduced to a matter of relative effectiveness of coatings rather than possibility of protection. Although a universally applicable method of protection still appears to be a long way off, results at this time indicate that the solution to the problem for special strategic applications is not far away.

4. Substantial quantities of the alloys are being made available for experimentation and for limited production items where oxidation resistance is not a prerequisite to sustained performance. Most, if not all, of the applications require developments in design if the full benefit of the new materials is to be secured. It can be expected that in the near future applications of the new materials will result in some revolutionary engineering developments.

Correspondence . . .

Flaws in Large Forgings

WATERTOWN, MASS.

I would like to comment on the problem of detecting small but dangerous flaws in large masses of metal – especially forgings – from the standpoint of a physicist who has been doing a considerable amount of development work on ultrasonic and other nondestructive test methods. The occasion is your comment toward the end of the review of "Recent Accidents With Large Forgings" which appeared in *Metal Progress* for February.

We seem to be passing through a period of time wherein extreme demands are being made upon metal products of all kinds. Perhaps this is not a new situation, but one gets the feeling that more is at stake now than before. Ultrasonic techniques have revealed many "indications" – possible sources of failure – which, because of the state of the art, cannot be pinned down as to their nature or magnitude without destructive examination. Such uncertainty of interpretation is inherent in all indirect tests, including the magnetic, radiographic, and others. I know of no short cut to this problem of interpretation.

Correlating these indications with the findings of destructive tests, upon which the validity and significance of the former are based, is a time-consuming and expensive operation.

Consider the dilemma faced by the engineers responsible for the "Arizona" rotor. On one hand, they had test data of questionable significance. On the other hand, they had incomplete data on the significance of various discontinuities on service performance. The economics of the situation then becomes the governing factor and educated guesses are the best that can be done, from a technical standpoint.

Those of us involved with the development and standardization of nondestructive tests understand this situation because it is the rule rather than the exception. It seems that a catastrophic failure or two is required to raise the level of effort to the point which can generate a solution in reasonable time.

Ultrasonically, "flaws" can be detected in almost any sample of metal. This relatively new tool is extremely powerful. In the over-all picture, it can reveal inhomogeneities in structure, mechanical properties and chemistry (segregation), the presence of macroscopic "flaws", dislocation behavior, magnetic behavior and other things. To determine which of these factors, singly or in combination, is responsible for the indication is virtually impossible at the present time. Hence, the use of these nondestructive techniques for acceptance or rejection varies widely with the complexity or uniformity of the product. Uusually, after the parts are accepted despite many "indications" and the first few catastrophic failures occur, the pendulum swings the other way and unwarranted rejections are frequently made, based largely on fear rather than facts.

In summary, the problem revolves around new tests which are only partially understood, new quality criteria which are not adequately described, and new demands on steel production practice which may be difficult to cope with. Considerable effort is now being devoted to unscramble the data from nondestructive tests. This effort must be allied to metals engineering progress to understand the causes of failure. It is an extremely slow process.

C. H. HASTINGS, Chief,
Nondestructive Testing Branch
Watertown Arsenal Laboratories

Snyder Furnace Still Operating

NORTH TONAWANDA, N.Y.

The article "Fifty Years of Progress in Electric Furnace Steelmaking", by Howard J. Stagg in the April issue of *Metal Progress*, was very interesting to us, especially the picture of the Snyder electric melting furnace, vintage 1915.

We have in our steel foundry a Snyder furnace installed about that time and still operating every day. It is a three-phase furnace with two electrodes through the roof and a water cooled bottom connection for the third phase.

There were many of these furnaces in operation in the United States during World War I and quite a few Greaves-Etchells.

We would be interested to know if we have the last of the Snyder furnaces still in operation in this country.

JOSEPH H. SANDER
President
Tonawanda Electric Steel
Casting Corp.

(More Letters on p. 112)

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Sleeve-Bearing Material

STEUBENVILLE, OHIO

When I read of Mr. Smith's search for a long-lived sleeve bearing in the Correspondence section of the April issue, I thought of three possible solutions. The requirements of chemical inertness, abrasion resistance and immunity to radiation damage are difficult and my suggestion was to try synthetics or plastics such as Nylon or Teflon, glass or other ceramic materials or graphite.

Fortunately, instead of writing immediately to Mr. Smith, I continued reading *Metal Progress* and found on p. 152 what appears to be a solution to his problem presented on p. 104. The advertisement of Dixon Corp. entitled "Here's Why Rulon Solves Bearing Problems" describes a bearing material whose properties appear to match almost exactly the requirements listed. It was such a remarkable coincidence that I could not refrain from calling it to your attention.

FRANK G. NORRIS
Metallurgical Engineer
Wheeling Steel Corp.

EDITOR'S NOTE – We too were surprised by this unusual presentation of problem and solution in the same issue. The Correspondence section was processed for printing several weeks before the Dixon Corp. advertisement was submitted and no one compared the two until after the April issue was published.

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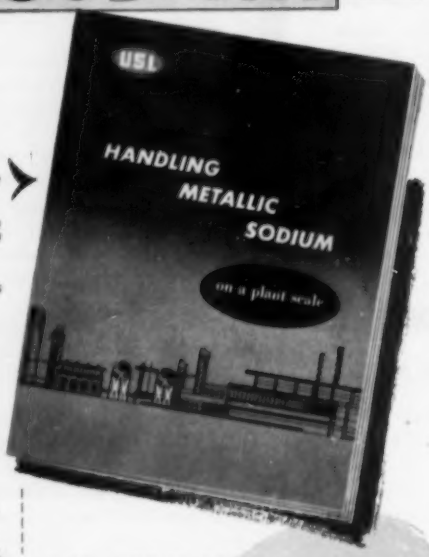

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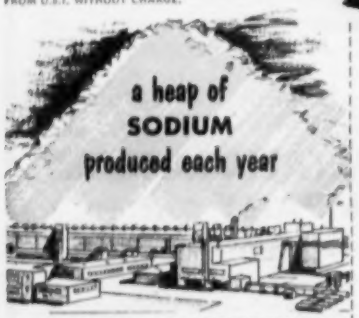

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METAL PROGRESS has recently been plagued with an epidemic of typographical errors, not all of them due to the printer – that handy whipping boy – but very embarassing, no matter who is responsible. To those who may have been misled when reading pages originally, or for those who keep their copies for binding, the following corrections are addressed:

Large Forgings – Minimum tensile strength of the steel on p. 54, February, should read 110,000 psi. (11,000, as shown, is for plastics.)

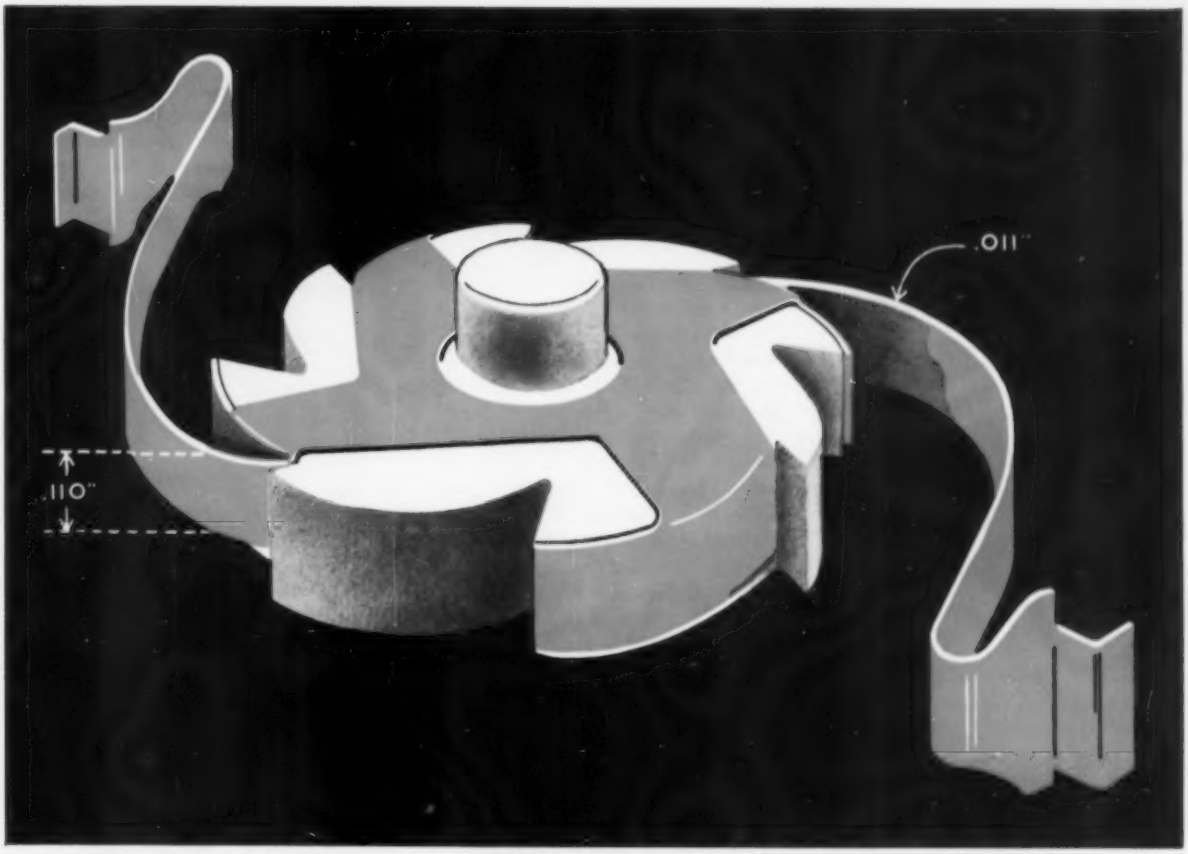
Turbine Blades – Vertical ordinates for the stress-to-rupture curves – Fig. 3, p. 54, March – should be doubled. (Rusty slide rule used when converting long tons per sq. in. to psi.)

Metallography – The micro on p. 100 of the May issue got turned upside down somewhere between the OK'd page proof and the printed magazine.

Aluminum Alloy Castings – The column headings in the table on p. 79 of the April issue were reversed. The mechanical properties after heat treatment are:

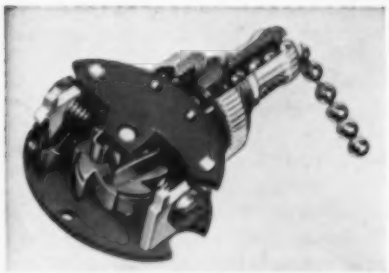
	356-T6	356-T71
Tensile strength	33,000	28,000
Yield strength	24,000	21,000
Elongation	3.5%	3.5%

LD-Process – This new steel-making process was worked out at the steel plants of Vereinigte Oesterreichische Eisen und Stahlwerke Aktiengesellschaft (VOEST), Linz, and Oesterreichische Alpine Montangesellschaft, Donawitz. The latter firm was not properly credited in the article starting on p. 49, January.



Enlargement showing the contact springs at the "heart" of one model of the Levolier® switch mechanism. Levolier switches are used in industrial and commercial lighting, in heavy-duty industrial sockets, in appliances, fixtures, etc.

The Anaconda alloy tailored for this punishing service actually costs less



Cutaway of Levolier Switch No. 41 shown approximately actual size.

THE PROBLEM: The McGill Manufacturing Company, Inc., Valparaiso, Indiana, was interested in a desirable substitute for a premium copper alloy used in contact springs for their widely known Levolier switch mechanisms. Unexcelled quality had to be maintained with a new alloy that would help hold prices against rising costs. As these switches are designed for long service and heavy-duty industrial service, the spring material has to be tough and durable.

THE SOLUTION: In 1952, McGill discussed the problem of an alternate spring material with a metallurgical engineer from The American Brass Company. After an analysis of the requirements, a special Anaconda alloy was offered—Ambronze-422, rolled to spring temper.

Samples were prepared and tested by McGill and Underwriters' Laboratories. The material performed satisfactorily in standard tests—current carrying capacity, 6 amps at 125 volts d.c.—readily exceeded the requirements of 75,000 cycles, or 150,000 individual operations.

In production, the new Anaconda alloy also performed satisfactorily. It was necessary to make only one minor die-forming change. McGill received a desirable saving in material costs—product quality remained high—and the material was available as needed to maintain production.

FREE TECHNICAL SERVICE: This is another example of the Anaconda technical service available to metal users. Sometimes a new alloy is required—other times a variation of a standard alloy will do the job. The Technical Department of The American Brass Company, through its day-to-day work with a wide variety of metal problems, offers a tremendous breadth of experience, which is at your disposal. See your American Brass Company representative or write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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Personal Mention

James I. Hoffman

JAMES I. HOFFMAN has been selected to head the metallurgy division of the National Bureau of Standards, succeeding JOHN C. THOMPSON, who recently retired. Dr. Hoffman, who has been serving as assistant chief of the chemistry division and chief of the surface chemistry section, will direct the Bureau's metallurgical research and development program.

Dr. Hoffman graduated from Franklin and Marshall College in 1918. After a year in the Chemical Warfare Service for the Army, he joined the Bureau in 1919 as a chemist. While at the Bureau, Dr. Hoffman continued his academic studies, receiving his Master's degree from George Washington University in 1921 and his Ph.D. from the American University in 1930.

Dr. Hoffman has made many significant contributions to chemical science during his years at the Bureau. He developed one of the first methods for purifying uranium oxide by an ether extraction process and determined the atomic weights of aluminum and gallium. During World War II, when bauxite supplies were scarce, he constructed a pilot plant for the production of alumina from clay. In 1946, Dr. Hoffman was awarded the Hillebrand Prize for these achievements, and more recently the Department of Commerce presented him the Gold Medal for Exceptional Service.

Paul Schwarzkopf

A 70th birthday does not mark the retirement of PAUL SCHWARZKOPF from his chosen field of powder metallurgy. As he said after his second cognac: "I prefer to brag about my youth rather than my age!" His youth was indeed notable, although at the time it doubtless seemed filled with difficulties. Some of these are delightfully related in his little book "Stories From Molybdenmark" – which is a collector's item, by the way.

Like so many in powder metallurgy, he started in the incandescent bulb industry, and devised some fundamental improvements in the manufacture of tungsten powder and nonsagging tungsten filaments. He

Paul Schwarzkopf

early became interested in the possibilities of molybdenum. By 1921 he had founded the Metallwerk Plansee at Reutte, Tyrol, Austria, and since has built it to a commanding position in the manufacture of hard carbide tools, porous bearings, metal filters, and metallic parts for X-ray and electronic devices. This was expropriated by the Brownshirts immediately after Hitler's Austrian Anschluss, and Dr. Schwarzkopf barely got away to America in time. Here he founded American Electro Metal Corp. in Yonkers, N. Y. Since the war he has recovered his Austrian property, and many foreign metallurgists have visited there during the powder metallurgy seminar in Reutte in 1952 and again in 1955.

J. L. McCloud

After nearly 43 years with the Ford Motor Co., Dearborn, Mich., J. L. MCCLOUD has retired from his position as staff consultant in the manufacturing engineering office.

Mr. McCloud joined the Highland Park Plant of the company soon after his graduation from University of Michigan in 1913. In 1917, he went to the Ford tractor plant and there set up the metallurgical and chemical laboratory. Later Mr. McCloud moved to Dearborn where he organized a research laboratory in conjunction with the engineering department.

During the Ford Motor Co.'s manufacture of airplanes, Mr. McCloud served as metallurgist and chemist, and continued as a consulting metallurgist and chemist for the engineering department. At that time he developed zinc chromate primers for aluminum alloys, now the almost universal primer for airplanes and other structures. In 1927, Mr. McCloud took over the examination of paints, paint manufacture and application for all activities of the Ford Motor Co., and served as finishing (painting) director for many years. His contributions in this field include the use of infrared lamps for local baking of enamels, and the application of baking enamels to automobile and truck bodies. In

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Another item is a high pressure gas valve, with a cast body and brass rod stem. The rod was changed to arsenical bronze, which costs a bit more, but it ended flaking and galling between stem and seat, and materially reduced rejects. Still another instance of Revere service concerns a hot water heater relief valve. The original model was cut out of bar stock. We suggested a high leaded brass tube, hexagon outside, round inside. This greatly reduces machining, has a better surface, and a better seat. Costs more by the pound, but saves more by the piece.

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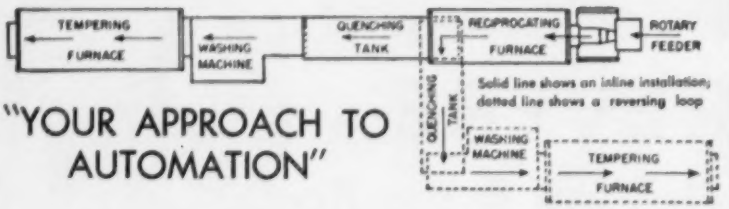

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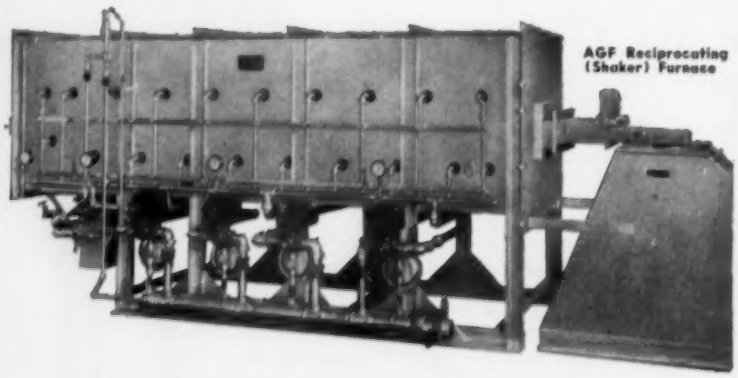

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The output ranges from 100 to 800 lbs. of controlled atmosphere heat treating, quenching, washing and tempering per hour. A wide range of sizes cuts costs; the unit is suitable for a small plant or can be fitted into a production line in a large plant.

The installation can be made either in line or in a reversing loop as illustrated. The reversing loop discharges the work next to the charging end of the furnace and uses a minimum of floor space.

Each part is individually heat treated and quenched as it passes through the reciprocating furnace and quench tank. The disadvantages of batch processing are eliminated.

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Personals . . .

addition to these activities, Mr. McCloud has directed work on the specification of materials and processes and served as lubrication and fuel consultant to the engineering department.

He is a past chairman and secretary of the Detroit Chapter, a director and president of the Engineering Society of Detroit, a vice-president for materials engineering of the Society of Automotive Engineers, and has been active in a number of other professional and civic organizations.

Robert C. Singleton was recently appointed vice-president in charge of engineering of the Nelson Stud Welding Div., Gregory Industries, Inc., Toledo, Ohio. Mr. Singleton, who joined the company in 1944, was formerly manager of industrial sales.

Paul G. Tomalin has been named general manager of the MacGregor-Comarain Div., National-U.S. Radiator Corp., Johnstown, Pa. For 14 years Mr. Tomalin was chief of the technical section, design division of the U. S. Coast Guard. He resigned in 1954 and until joining the MacGregor-Comarain Div. was manager of sales and engineering in the Washington, D. C., office of the Maxim Silencer Co.

Sidney L. Simon is now manager, applied research department, advanced development division of Arco Manufacturing Corp., Stratford, Conn.

Harold F. Bishop was awarded the Joseph S. Seaman Gold Medal of the American Foundrymen's Society for "outstanding contributions to castings research at the Naval Research Laboratories" at the annual AFS Castings Congress and Show. Mr. Bishop is head of the melting and casting section of the Naval Research Laboratory, Anacostia Station, Washington, D. C. At the same Congress, **James S. Vanick** received the William H. McFadden Gold Medal for "valuable service to the ferrous castings industry over many years". Since 1922, Mr. Vanick has been connected with the International Nickel Co. as research metallurgist.

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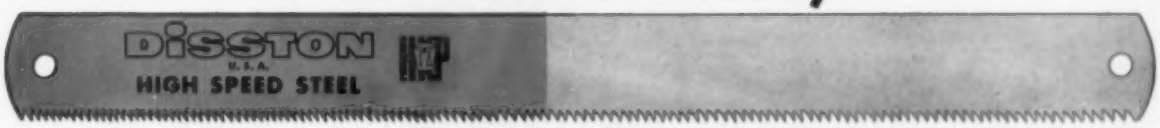

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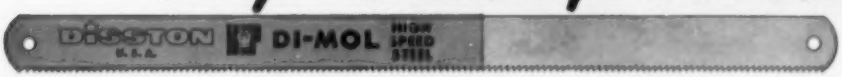

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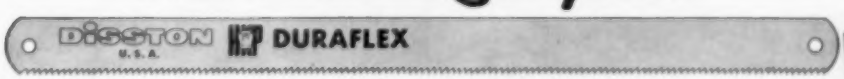


INDUSTRIAL DISTRIBUTOR

WRITE FOR LATEST CATALOG AND HACK SAW SELECTOR TODAY.

Henry DISSTON DIVISION
H. K. PORTER COMPANY, INC.
7102 Tacony, Philadelphia, 35, Pa.

Cambridge

WOVEN WIRE CONVEYOR BELTS take the "hot spots" out of ANNEALING & BRAZING

FREE CIRCULATION of heat and gases through the all-metal belt and around the work permits continuous, uniform heating and cooling as work moves through your plant.

By combining controlled movement with free circulation of process atmospheres, Cambridge Woven Wire Conveyor Belts eliminate batch annealing and brazing. There is no formation of "hot spots" which produce local stresses. Continuous, belt-to-belt flow through subsequent quenching and washing operations as well as heating, cuts costs and provides fast, uniform production.

Not only does the open mesh construction provide free circulation of gases . . . it also permits rapid drainage of process solutions. The all-metal belt is corrosion resistant and impervious to damage at temperatures up to 2100°F. Cambridge belts have no seams, lacers or fasteners to wear more rapidly than the body of the belt . . . no localized weakening.

Cambridge Woven Wire Belts for heat treating are made in any size, mesh or weave, and from any metal or alloy. Special retaining edges or cross-mounted flights are available to hold your product during inclined movement.

Call in your CAMBRIDGE FIELD ENGINEER to discuss how you can eliminate batch handling from your heat treating. Look under "BELTING, MECHANICAL" in your classified phone book. OR, write for your copy of Special Report, "6 Ways to Increase Heat Treating Production" and 130-PAGE REFERENCE MANUAL giving mesh specifications, design information and metallurgical data.

The Cambridge Wire Cloth Co.

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

Department B, Cambridge 7, Maryland

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

Personals . . .

Edward J. Kizak, formerly chief, quality control, Winston-Salem Air Procurement Office, Atlanta Air Procurement District, has assumed new duties with the Procurement Div., Headquarters Air Matériel Command, quality control, as project officer for tactical, strategic and intercontinental and intermediate range ballistic missile.

Harold N. Ewertz, after 34 years in the welding industry, has started his own business as manufacturer's representative for the Raytheon Mfg. Co., Waltham, Mass.

Andrew D. Lauver, formerly employed by Kaiser Steel Corp., Fontana, Calif., is now a process engineer at Hughes Aircraft Co., Tucson, Ariz.

Leonard M. Taussig is now technical director of Taussig Associates, Chicago. Mr. Taussig was formerly chief metallurgist for the Magnaflux Corp., Chicago.

C. Richard Hocker is now New England district manager, high voltage switch gear, for the Federal Pacific Electric Co.,

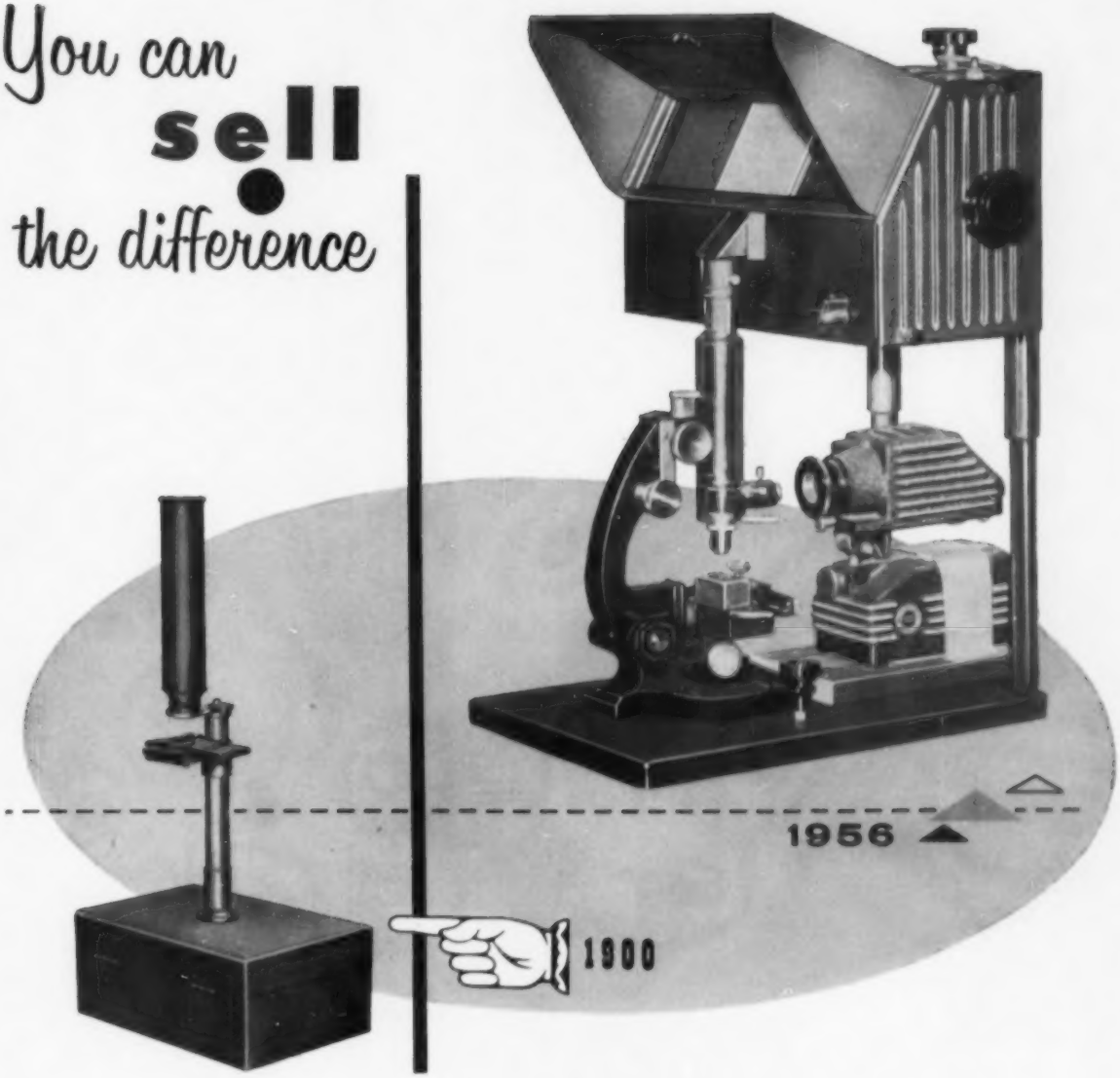
Arlen S. Kjelby has left the National Cash Register Co., Dayton, Ohio, to join the staff of Metcut Research Associates, Cincinnati, Ohio, as a staff engineer.

Gedale D. Davis has been transferred from the Halethorpe, Md., extrusion plant of Kaiser Aluminum and Chemical Corp. to the Kaiser sheet and plate mill in Spokane, Washington. Mr. Davis joined Kaiser in 1955 after his release from active duty with the U. S. Navy.

Harry J. Weil, after release from two years of active duty in the armed services, recently accepted employment as a test project engineer in the engineering department of Alco Products, Inc., Schenectady, N.Y. While serving in the U.S. Army, Mr. Weil was stationed at Aberdeen Proving Grounds, Md., as a metallurgist in the engineering laboratories of the development and proof services.

Harold C. Schanck, Jr., is now chief engineer at Stainless Welded Products, Inc., Jersey City, N. J.

You can sell the difference



The pocket-size "personal" microcsope shown at the left was one of the first metals research and quality control instruments in daily use at Scovill more than half a century ago.

By contrast, the instruments used today are not only infinitely more precise, but are also able to complete the most searching examination of alloy samples in a fraction of former time.

Continual tightening of Scovill standards has been matched by equally constant improvement in precision testing methods employed to maintain them. This is one of the reasons why Scovill Brass and Aluminum Mill Products are known far and wide for exceptional uniformity and close adherence to customers' specifications . . . lot after lot . . . order after order.

Scovill Manufacturing Company, Mill Products Division, 99 Mill Street, Waterbury 20, Connecticut. Phone Plaza 4-1171.

SCOVILL **MILL PRODUCTS**
BRASS • BRONZE • NICKEL SILVER • ALUMINUM

12SC56

Since 1939, when the introduction of Malleabrasive revolutionized blast-cleaning, there has been only one MALLEABRASIVE!

MALLEABRASIVE was developed through exhaustive research. Its leadership has been maintained through continuing research and improvement.

- Today there is still only one genuine MALLEABRASIVE.
- MALLEABRASIVE has no exact counterpart—there is no other product exactly like it.
- MALLEABRASIVE is patented because of its own distinctive metallurgical characteristics.
- MALLEABRASIVE is produced only by manufacture under the full and complete MALLEABRASIVE process—used by Globe exclusively.

The qualities that make Malleabrasive distinctively different have made it the most widely used premium abrasive in the world today. In hundreds of plants it has made important reductions in blast-cleaning costs. Undoubtedly it can do the same in yours. At least, why not investigate its possibilities? Write us.

THE GLOBE STEEL ABRASIVE COMPANY
MANSFIELD, OHIO
Subsidiary of Pittsburgh Crushed Steel Co., Pittsburgh, Pa.
Also sold and recommended by Pangborn Corp., Hagerstown, Md.

MALLEABRASIVE®

Personals . . .

A. L. Boegehold, past president, was recently named manager of research staff activities of General Motors Corp., Detroit. An employee of General Motors since 1920, Mr. Boegehold last held the position of assistant to the general manager of the research laboratories.

William D. McMillan has been awarded honorary life membership in the American Foundrymen's Society for "outstanding contributions to the Society and the ferrous castings industry". Mr. McMillan has served in chemical and metallurgical capacities for International Harvester Co. since 1923 and now holds the position of supervisor of metallurgy for the farm implement division at the McCormick Works, Chicago.

Robert H. Colmer has been transferred to the St. Bernard factory, Cincinnati, Ohio, of the Procter & Gamble Co., as plant engineer. Mr. Colmer was master mechanic at the Pantex Ordnance Plant, Amarillo, Tex., operated by the Procter & Gamble Defense Corp., until he was transferred.

S. W. Kessler, Jr., recently discharged from the U. S. Army, has returned to his position of research metallurgist for the Lancaster, Pa., division of the Radio Corp. of America. While in the service, Mr. Kessler did metallurgical research at the ballistics research laboratory, Aberdeen Proving Grounds, Md.

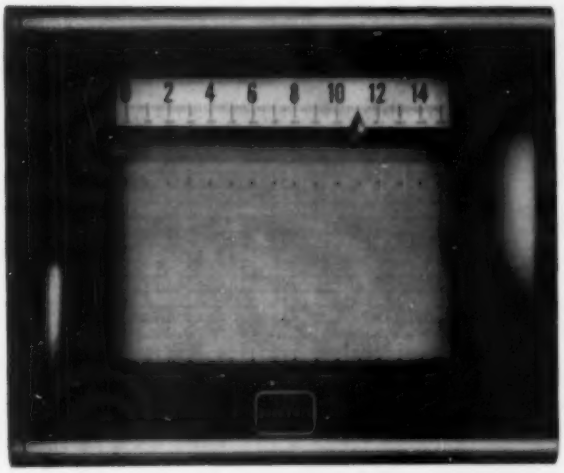
Norman H. Deunk, Jr. is now in charge of the heat treating and metallurgical department at Staples Tool Co., Cincinnati, Ohio. Prior to this appointment, Mr. Deunk spent seven years in the metallurgical department of the National Twist Drill & Tool Co., Rochester, Mich.

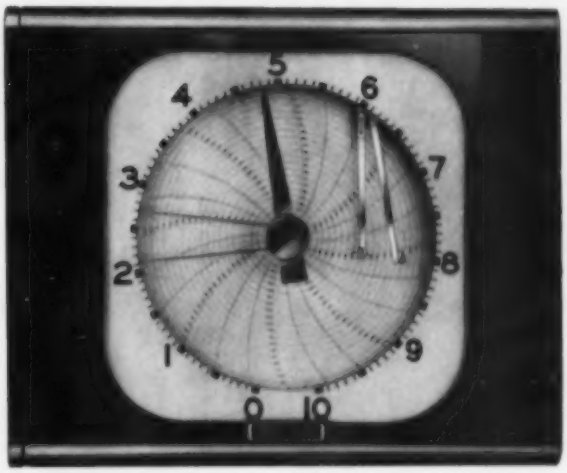
Harry W. Dietert has been elected vice-president of the American Foundrymen's Society. Mr. Dietert is chairman of the board of his own company, the Harry W. Dietert Co., Detroit, which he founded in 1925.

S. A. Rothman, formerly in charge of the Detroit district office of the Interior Steel Equipment Co., Cleveland, is now assistant to the president in the home office.

WHAT'S NEW AT BRISTOL...

Three Ways to Better Temperature Control





BRISTOL ELECTRONIC DYNAMASTER® POTENTIOMETERS

CONTINUOUS STANDARDIZATION WITH NO DRY CELLS: Bristol Dynamaster Potentiometers with No-Batt Continuous Standardization which eliminates need for dry cells. Results: no interruption in operation for standardization, no batteries to replace.

A MODEL FOR EVERY REQUIREMENT: Dynamaster Potentiometers are available as single-pen, two-pen, and multiple-record (up to 24 points) *strip-chart* instruments and as *round-chart* instruments.

ELECTRIC AND PNEUMATIC CONTROLLERS. Both strip- and round-chart instruments are made in a very wide variety of controllers that meet every furnace and oven control requirement, including the following in a great many forms:

Electric Control — on-off, average position, proportional input, 3-position, proportioning, proportional with automatic reset, and time-program.

Pneumatic Control — on-off, proportional, and proportional with reset.

FREE-VANE® ELECTRONIC PYROMETER CONTROLLERS

- **Very minute changes in temperature** at the control point (less than 0.003" on scale) closes or opens the Thyratron-operated relay with positive trigger action.
- **New high-torque, rugged millivoltmeter measuring mechanism** gives greater accuracy — Alnico V magnet — and a sensitivity of 15 ohms per millivolt.
- **Separate control units are plug-in.**
- **Wide variety of models** — available in thermocouple and radiation pyrometer controllers in ranges up to 4000°F for L, H, LH, LOH, and LNH control and for L and H with proportional input control.

FOR MORE FACTS about these three rugged Bristol Furnace and Oven Controls write for free Bulletin PI260 today. It's a 48-page booklet of useful data, specifications, control diagrams and prices for every type of automatic heating control. The Bristol Company, 106 Bristol Road, Waterbury, Conn. S.5

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POINTS THE WAY IN HUMAN-ENGINEERED INSTRUMENTATION

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

DURALOY

A good example of our
WELDING
TECHNIQUE

in connection with high alloy casting

This tube support is 21'6" long; 6'7" wide and weighs 8900 pounds. It looks like a single casting. Actually it is made up of three sections welded together in zig-zag strips across the face. It's a Duraloy HH casting destined for an oil refinery cracking still.

Welding is assuming greater and greater importance in the production of high alloy castings. Often it is the only way to produce large tonnage or unusually shaped pieces. During our many years of experience in producing both high alloy static and centrifugal castings, we have developed sound welding techniques for such castings. Carbon steel welding techniques won't serve. It takes special know-how for chrome-iron and chrome-nickel.

You can rest assured that if the chrome-iron or chrome-nickel castings you order from us require any welding, it will be done skillfully.

THE DURALOY COMPANY
OFFICE AND PLANT: Scottdale, Pa.
EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.
DETROIT OFFICE: 2395 Woodward Avenue, Pleasant Ridge, Mich.
CHICAGO OFFICE: 332 South Michigan Avenue

SEND FOR YOUR COPY of our New General Bulletin.

Personals . . .

James A. Corson, having completed his tour of duty with the U.S. Army, has resumed his position as senior negotiation engineer with the aviation gas turbine division of the Westinghouse Electric Corp., Kansas City, Mo. While in the Army, Mr. Corson was stationed at Aberdeen Proving Ground, Md., conducting research on personnel ejection systems for high-speed aircraft.

A. Jack Moore has recently rejoined Canadian Bronze Co., Ltd., Montreal, Quebec, as executive vice-president. Mr. Moore was formerly regional manager, eastern Canada, of Vanadium-Alloys Steel Co. of Canada, Ltd.

Frederick P. Brodell has left the U.S. Bureau of Ships to become a metallurgist at Consolidated Vultee Aircraft Corp., San Diego, Calif.

James A. Burbank II, formerly with National Extrusions, Inc., Arlington, Va., has joined the sheet and plate finishing department of the Ravenswood, W.Va., works of Kaiser Aluminum and Chemical Corp.

Earl R. Asch, formerly assistant manager of the production engineering division at Solar Aircraft Co., San Diego, has been promoted to manager of the division. Mr. Asch came to Solar from the aircraft engineering division of Ford Motor Co.

J. P. Clark, Jr., is now working for General Electric Co., Louisville, Ky., as a laboratory technician.

A. R. Schmitt has been transferred from the Pittsburgh district of the U.S. Steel Supply Div., U.S. Steel Corp., to the Houston district and is now located at the Dallas warehouse.

Robert T. C. Rasmussen recently joined the staff of the technical division of Vanadium Corp. of America at the Cambridge, Ohio, research center. Mr. Rasmussen was a consulting metallurgist prior to this position.

Stuart Solomon, following his separation from the U.S. Army, has accepted a position as development metallurgist with U.S. Steel's Duquesne, Pa., works.

TITANIUM STRIP is descaled continuously on time cycles as low as 30 seconds, with excellent results.

10-MINUTE IMMERSION loosens scale on 5 tons of stainless wire. A water quench, 3-minute acid dip, and final water rinse produce a clean, bright surface with no pitting or etching.

Use this fast, safe Hooker Process for descaling steel and titanium

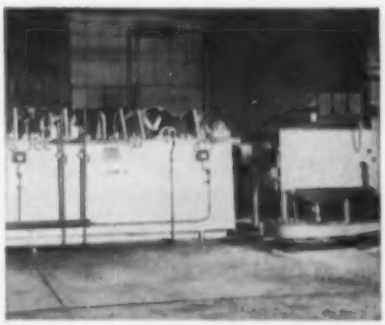
Descale alloy steels and titanium in any form—rapidly, safely—using the Hooker Process with Virgo® Descaling Salt.

A bath of molten Virgo Descaling Salt quickly converts scale, rust, and other surface impurities to an acid-soluble coating. A quench, acid dip, and final spraying then remove this coating in from one-tenth to one-hundredth the usual pickling time, with no measurable effect on the base metal.

You can easily set up the Hooker Process for batch or continuous operation on any form of work including strip, sheets, bars, wire, tubes, plate, castings, forgings, and fabricated parts. You can usually process work as fast as your handling methods allow, with a minimum of supervision. Operation is safe for personnel, and there is little or no spent-acid disposal problem.

You can profit by the experience of more than 50 companies now using the Hooker Process successfully to speed up descaling of alloy steels and titanium in practically every form.

You'll get quick service on any descaling problem, by writing or phoning us. Complete test and engineering facilities are at your disposal, without obligation.



LIGHT-GAUGE ALLOY STRIP is descaled at 20-35 ft. per min. in this Virgo bath, after annealing.

Send for these bulletins—Get the whole story on Virgo Descaling Salt for alloy steels and titanium . . . how the Hooker Process works, its advantages, how to set up a Virgo descaling line, and the services you enjoy as a user. No obligation. Write us today.

From the Salt of the Earth

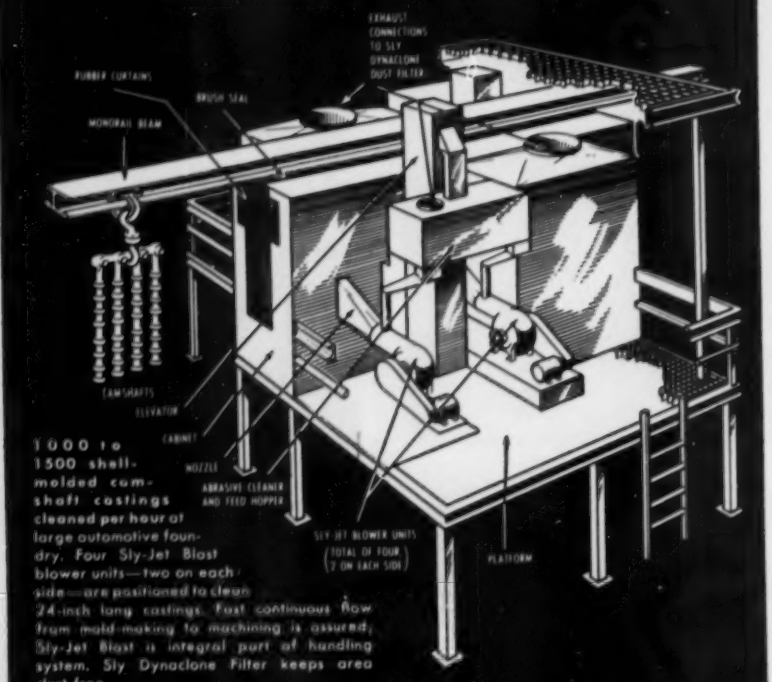
HOOKER ELECTROCHEMICAL COMPANY

405 Forty-seventh St., Niagara Falls, N. Y.

NIAGARA FALLS • TACOMA • MONTAGUE, MICH. • NEW YORK • CHICAGO • LOS ANGELES

HOOKER CHEMICALS

NEW LOW-COST WAY TO CLEAN SHELL-MOLDED CASTINGS



1000 to 1500 shell-molded camshaft castings cleaned per hour at large automotive foundry. Four Sly-Jet Blast blower units—two on each side—are positioned to clean 24-inch long castings. Fast continuous flow from mold-making to machining is assured; Sly-Jet Blast is integral part of handling system. Sly Dynaclone Filter keeps area dust-free.

NEW SLY-JET BLAST

Eliminates need for air compressor . . . Eliminates maintenance costs of airless wheels

Now, clean shell-molded castings faster, at lower cost. With new, *low-velocity* Sly-Jet Blast, cleaning action is thorough yet "gentle"— therefore, no pitting, no removal of parent metal, no warping or distortion as with other cleaning methods. *Efficient*—abrasive is accurately directed over a large work area through a stationary nozzle, which can be set at any angle from horizontal to vertical. *Economical operation*—blower unit is powered by electric motor; there is no compressor, no need for high horsepower. *Long, trouble-free operation*—there are no moving parts in the blast zone; abrasive is introduced directly into the nozzle. *Versatile*—nozzle opening can be in any shape from circular to rectangular and any size. Abrasive can be any grade of sand, most grades of grit. *Non-stop operation*—cleaning mechanisms can run continuously for effective integration in continuous-flow handling systems.

Take the problem and expense out of cleaning shell-molded castings. Write today for the facts on new Sly-Jet Blast.

THE W. W. SLY MANUFACTURING CO.

SINCE 1876

4788 TRAIN AVENUE • CLEVELAND 1, OHIO

OFFICES IN PRINCIPAL CITIES

Personals . . .

Carl A. Liedholm, a 25-year ASMember, has resigned from his position with Westinghouse Commercial Power Activity to become project engineer in the nuclear department, research division of Curtiss-Wright Corp. (During World War II he was chief engineering metallurgist for Curtiss-Wright's propeller division.) He will be stationed in Clifton, N. J., until the new facilities at Karthaus, Pa., are ready.

R. P. Donnell has been promoted to the position of district manager of the New York steel and tube division, Timken Roller Bearing Co., Canton, Ohio. Joining Timken in 1939 as a metallurgical engineer, Mr. Donnell was district manager of the Cleveland district from 1943 until his promotion.

Albert J. Fischer, formerly director of research and development for Adamas Carbide Corp., Kenilworth, N. J., has been named works manager of the company. Mr. Fischer has been with Adamas Carbide since 1948.

Harold Smallen has accepted a position as research engineer with Northrop Aircraft, Inc., Hawthorne, Calif. Mr. Smallen was previously associated with the U. S. Naval Ordnance Test Station located at China Lake, Calif., where he was head of the methods development branch.

Clarence P. Sander, general superintendent, Vernon Plant, Consolidated Western Steel Div., U. S. Steel Corp., Los Angeles, has been elected first vice-president of the American Welding Society at the Society's annual meeting in Buffalo. Mr. Sander has been with the company since 1934.

James M. Copeland has been appointed senior project metallurgist for International Business Machines Corp., Endicott, N. Y. Joining the corporation in 1951 as a technical engineer in the metallurgical laboratory, Mr. Copeland was named associate metallurgist in 1952 and a year later became project metallurgist, holding this position until his recent appointment.

Warren L. Larson is now a metallurgist with Nuclear Metals, Inc., Cambridge, Mass.

CHASE® NICKEL LEADED COMMERCIAL BRONZE

For making STRONGER PRODUCTS *that have to be machined!*

This is the high-strength leaded commercial bronze you have been looking for! It has *27 percent higher tensile strength, 20 percent higher yield strength* than Leaded Commercial Bronze, yet has a machinability rating that is 80% of that of Free-Cutting Brass.

Chase Nickel Leaded Commercial Bronze is a moderately priced alloy for making longer-lasting pole line hardware, electrical fasteners, nuts, bolts, and other bronze products that require added strength. Order Chase Nickel Leaded Commercial Bronze today. It's available in rod form—round sizes from ¼" to 1" diameter, hexagonal sizes from ¼" to ⅞".

"IN THE CHIPS"—a Chase movie showing Brass Rod and Wire *at work*. Every machine shop can benefit by showing it. Loaned free on request.

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The Nation's Headquarters for Brass, Copper and Stainless Steel

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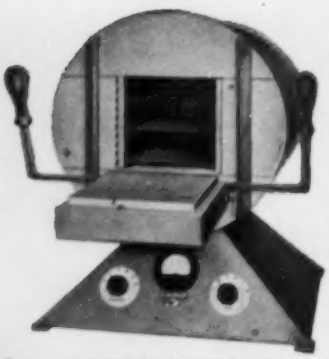
CRUCIBLE FURNACE

Used for melting small quantities of metals. Maximum temperature 1950° F. Five standard sizes. Other types available for 2300° F. operation.

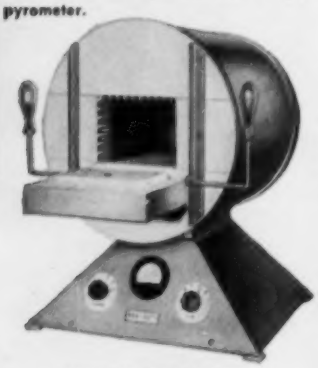


AIR DRAW FURNACE

Temperatures to 1250° F. A high speed fan circulates the air assuring uniform heating. 48 Steps of Temperature control — Indicating pyrometer.

TRADE MULTIPLE UNIT MARK

LABORATORY FURNACES AND HOT PLATES

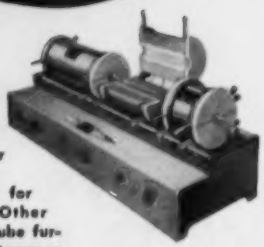


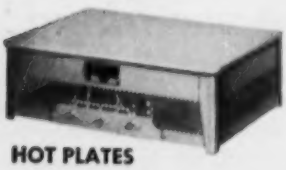
MUFFLE FURNACE

Temperature to 1850° F. Features include . . . low heat loss . . . rapid heating . . . better control with a 36 step tap-changing transformer . . . indicating pyrometer. Four standard sizes.

ORGANIC COMBUSTION FURNACE

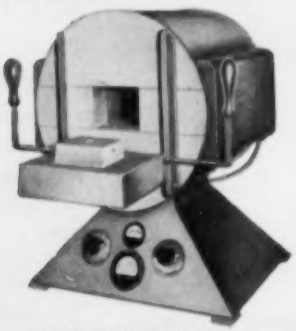
Three separately controlled tube furnaces mounted on slide rails, for use individually or as one assembly. Hinged construction for easy operation. Other sizes and types of tube furnaces available for temperatures to 2600° F.





HOT PLATES

7 Standard sizes, each with 3 heat control. Temperatures to 750° F.

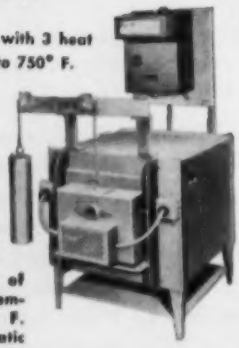


HIGH TEMPERATURE FURNACE

Temperature to 2600° F. Heating elements are silicon carbide rods which are easily replaced. Inside dimension 4" W. x 7" L. x 3" H. 48 step Temperature control with indicating pyrometer

MULTIPLE UNIT FURNACE With Controlling Pyrometer

Specially designed for heavy laboratory work. Heating on five sides of the furnace chamber. Temperatures to 1850° F. Available with automatic temperature control.



HEVI DUTY ELECTRIC COMPANY

LABORATORY FURNACES MULTIPLE UNIT ELECTRIC EXCLUSIVELY

MILWAUKEE 1, WISCONSIN

Personals . . .

S. M. Norwood will head the new marketing research division in the sales department of the Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., New York. Mr. Norwood, a vice-president of the company, has announced several appointments to the division. **Russell Franks** has been named manager of the marketing research division. Mr. Franks joined the parent company in 1921 and was appointed chief metallurgist of the research laboratories in 1943. In 1946 he was transferred to Electromet as chief metallurgist of the technical service and development group and in 1950 he was made manager of development. **G. A. Sands** and **R. L. Pope** have been appointed assistant managers in the marketing research division. Mr. Sands has been with Electromet since 1937. He became assistant manager of development in 1950 and three years later was appointed manager, secondary markets of the technical service and development department. Mr. Pope joined the company in 1952 as a metallurgical engineer in the technical service and development department located in the Chicago office. Two years later he was transferred to the New York office.

H. P. Rassbach has been named manager of the new metallurgical service division of the Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., New York. The new division will have its headquarters in Cleveland. Mr. Rassbach joined Electromet in 1950, after 25 years with the Midvale Co., Philadelphia. **R. A. Clark**, who has been with the company since 1945, was appointed manager, foundry service, in the division. **R. J. Portmann**, an employee of Electromet since 1937, has been named manager, openhearth service, and **H. C. Aufderhaar**, who also joined the Electromet organization in 1937, is now assistant to the manager.

Paul Diljak is presently a metallurgical engineer working in the metallurgy pilot plant at the tungsten and chemical division of Sylvania Electric Products, Inc., Towanda, Pa.

'dag' dispersions . . . *a touch does so much!*

Colloidal Graphite saves $25,000 a year on jet-blade forging

In the close-limit forging of a jet-turbine blade, a prominent manufacturer found that by using **'dag'** Colloidal Graphite on the dies, only one blow was needed to go from upset billet to final blade shape. Besides eliminating the second hammer-blow previously required, intermediate descaling and reheating operations were also avoided . . . for a total yearly saving of some $25,000 on this single operation.

Both oil-based and water-based **'dag'** Colloidal Graphite dispersions are widely used in forging operations. Diluted and sprayed on the dies, the colloidal graphite forms a slick lubricating film . . . protects the expensive dies and improves metal flow during forging.

Pretreatment of new dies with **'Aquadag'** — colloidal graphite dispersed in water — has paid off handsomely, too. Some firms estimate a 50% greater usable life from forging dies given this protective film of colloidal graphite before being put into service.

The benefits of **'dag'** dispersions for forging and other metalworking applications are discussed in Bulletin 426. Ask for your free copy.

100th Anniversary

1851—SILICON CARBIDE
1895—SYNTHETIC GRAPHITE
1906—COLLOIDAL GRAPHITE

ACHESON COLLOIDS COMPANY

PORT HURON, MICHIGAN

. . . also Acheson Colloids Ltd., London, England

ACHESON COLLOIDAL DISPERSIONS:
Graphite • Molybdenum Disulfide • Zinc Oxide
Mica and other solids.

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Acheson Colloids Company
Port Huron, Michigan, Dept. C-7

Yes, I want your free bulletin describing **'dag'** Dispersions for Metalworking.

Name_____

Title_____

Company_____

Address_____

City_____ State_____

ROLOCK
FABRICATED ALLOYS

HEAT AND CORROSION RESISTANT

USUALLY . . . the UNUSUAL is a job for ROLOCK

The two entirely different welded alloy fabrications shown here are typical of hundreds of tough high-heat-resistant equipment problems we have solved successfully.

When you bring such problems to Rolock, you benefit by the experience of an engineering and production team that has been exceptionally successful in this difficult field.

Your equipment is built by Rolock specialists in welded fabrication of high-heat-resistant alloys . . . men who know just how to handle these special materials for best results.

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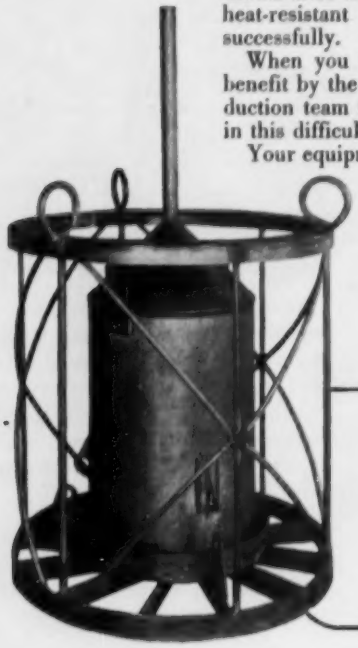

for example . . .

This Inconel retort, sand seal pan, grid support and lifting frame is one of many intricate Rolock welded fabrications for high-heat operation. It is used for brazing in a hydrogen atmosphere, alternately heated to 2200° F., lifted out of the furnace and cooled.

Size: Retort 24" diameter x 46⅝" long, excluding pipe. Supporting frame 46⅛" diameter x 57½" O.A. Weight: 200 lbs.

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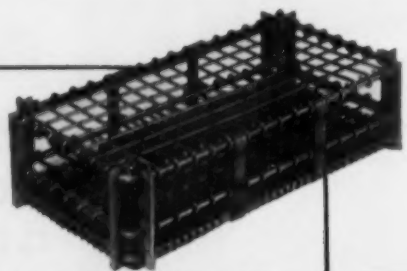

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Personals . . .

Paul D. Wright was recently appointed research engineer in the advanced development section of the Carboloy Dept., General Electric Co., Detroit. Mr. Wright was formerly associated with fuel element development engineering at Hanford Atomic Products Operation, General Electric Co., Richland, Wash.

J. J. Chyle, director of welding research, A. O. Smith Corp., Milwaukee, Wis., has been elected president of the American Welding Society at the Society's annual meeting in Buffalo, N. Y. Joining the A. O. Smith Corp. in 1925, Mr. Chyle has been director of welding research since 1937.

William T. Carey, formerly with the Ferrotherm Co., Cleveland, has recently been appointed metallurgist in the mechanical engineering development group at the Y-12 plant of the Union Carbide Nuclear Co., Oak Ridge, Tenn.

Samuel W. Gearhart, Jr., has been appointed sales and service engineer of the Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa. Mr. Gearhart joined the company after nine years as metallurgist and supervising metallurgical engineer for Baldwin-Lima-Hamilton Corp., Eddystone division, Eddystone, Pa.

H. George De Young was recently named president of Atlas Steels Ltd., Welland, Ont. Since joining the company in 1951 as works manager, Mr. De Young has held the positions of vice-president of operations and more recently executive vice-president. Prior to this time he was assistant to the president of Treadwell Engineering Co., Easton, Pa.

Albert M. Talbot has received a vice-presidential post at Austenal Laboratories, Inc., New York. Mr. Talbot will serve as vice-president in charge of the microcast division of Austenal and also continue in his present position as director of research. Associated with the company since 1953, Mr. Talbot was formerly a research metallurgist with the International Nickel Co., Bayonne, N. J., for 18 years.

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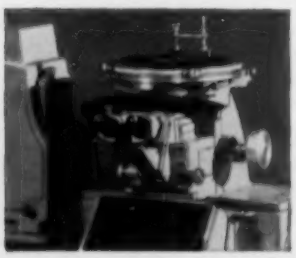

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Personals . . .

Tun Aung Kyaw, a Burmese student here on a government scholarship, is now studying metallurgy at the Missouri School of Mines and Metallurgy. After graduation, Mr. Kyaw will return to Burma to work in the steel industry there.

William E. Beyer has accepted a position as quality control metallurgist with the Glen L. Martin Co., Baltimore, Md.

G. A. Lenning has been appointed to the technical department of the metallurgical research division staff, Titanium Metals Corp. of America, at Henderson, Nev. Before joining Titanum Metals, Mr. Lenning spent five years at Battelle Memorial Institute where he worked in the titanium metallurgical laboratory and served as principal metallurgist on Army Ordnance and Air Force investigations concerning hydrogen in titanium.

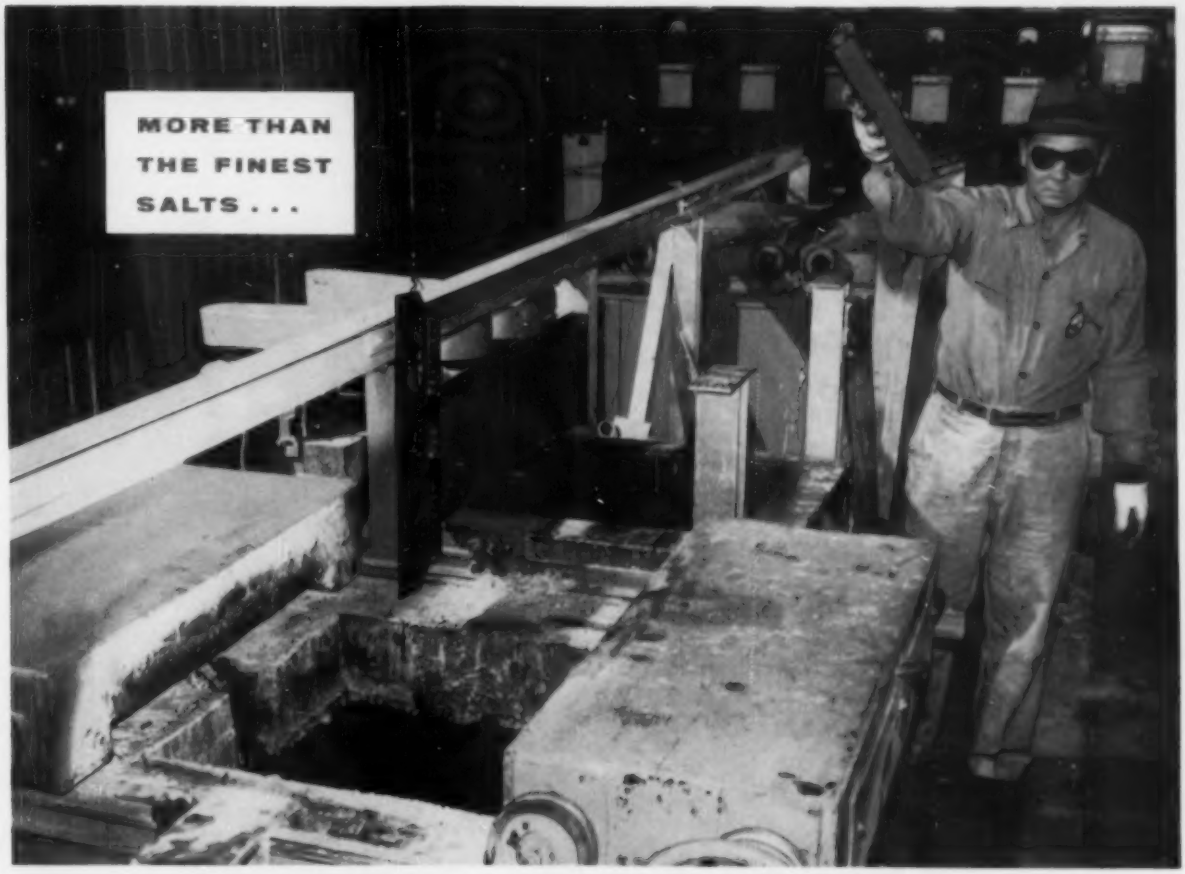
Ray McBrian has been appointed director of research of the Denver and Rio Grande Western Railroad Co., Denver.

Thomas J. Chakos has joined the Chicago sales organization of Barber-Colman Co., Rockford, Ill. Mr. Chakos was formerly with Minneapolis-Honeywell Regulator Co.

Albert Raitzer has been added to the staff of the products engineering department of the Trane Co., La Crosse, Wis., as a project engineer. Mr. Raitzer formerly supervised a metallurgical group on jet engine development for Thompson Products, Inc., Cleveland.

Morris W. Jones has been appointed general sales manager for Sargeant and Wilbur, Inc., Pawtucket, R.I. Prior to this position, Mr. Jones had been associated with Gulf Oil Corp., and C. I. Hayes, Inc., Providence, R. I.

Samuel A. Ott has been appointed works manager of the Claymont, Del., plant of the Colorado Fuel and Iron Corp. Prior to joining the company, Mr. Ott was superintendent of the Midvale Co., Philadelphia. Previously he was chief metallurgist and assistant to the vice-president of the Penn-Ohio Steel Corp., Birdsboro, Pa.



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The Houghton Man will be glad to work with you to get fast, uniform metal treatment, batch after batch. He'll recommend the Liquid Salt Bath you need for tempering, martempering, annealing, quenching, carburizing, nitriding, normalizing and hardening of metals. And he'll stay on your team till the job satisfies you!

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Personals . . .

Allan H. Lee has become a member of the technical sales staff of Pennsalt Chemicals of Canada, Hamilton, Ont. Until his recent appointment Mr. Lee was a technical service representative of Canadian Industries, Ltd.

Harold Ray, formerly a sales trainee in the customer service department of Sharon Steel Corp., Sharon, Pa., has been promoted to the position of sales representative in the Philadelphia district sales office. Mr. Ray has been with the company since 1945.

R. A. Shattuck has been named manager of Philadelphia sales for the Edgcomb Steel Co., Philadelphia. Mr. Shattuck has been associated with the company for the past 12 years in the capacity of product manager, toolsteel.

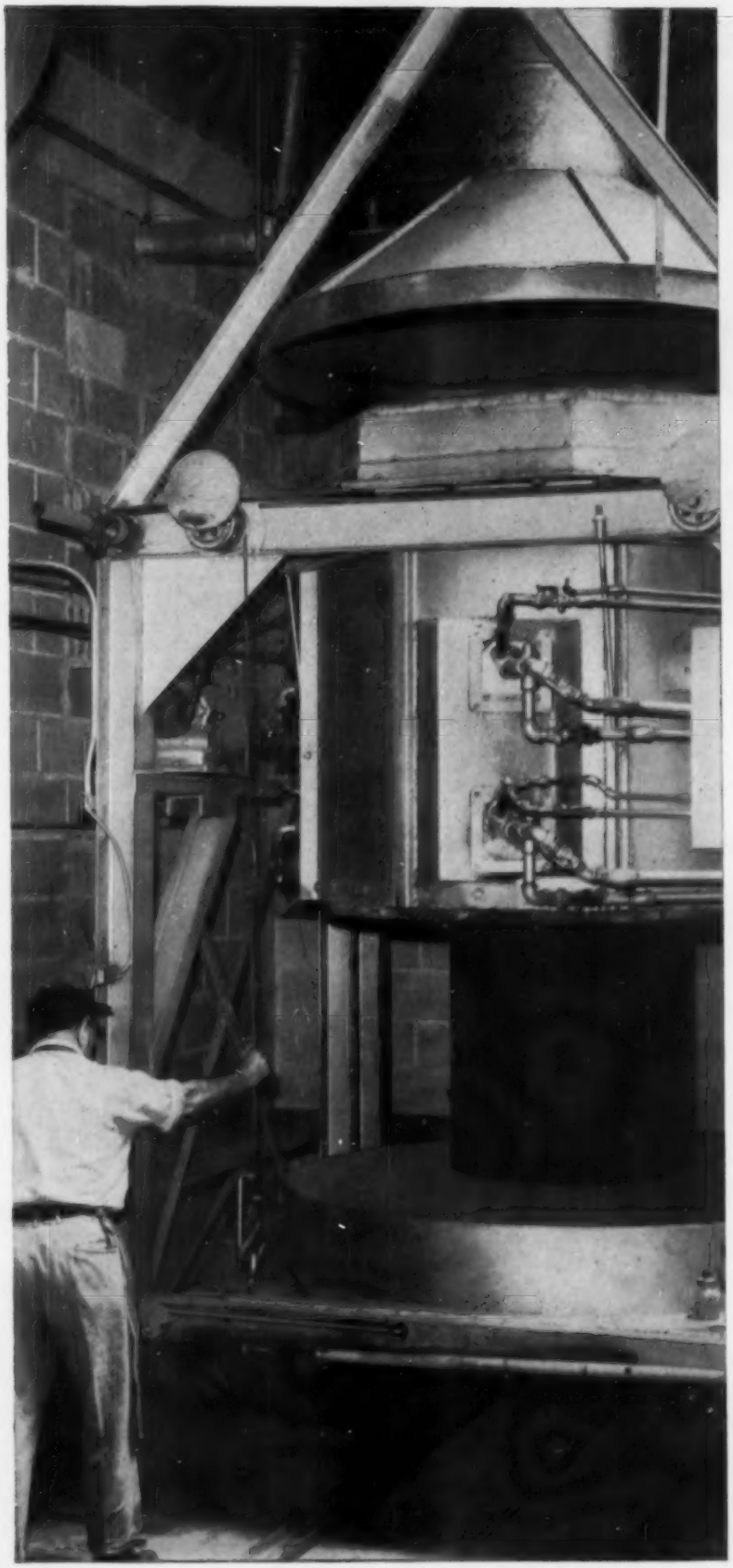
Robert D. Heetfield, recently released from military service, has been appointed metallurgist at the gaseous diffusion plant of the Union Carbide Nuclear Co., Paducah, Ky.

F. H. Buttner has been appointed group manager of the market research, product and process development department, Electro Metallurgical Co., Niagara Falls, N. Y. Before joining Electromet in 1953, Dr. Buttner was connected with the National Academy of Sciences, Washington, D. C.

Earl F. Adkins, recently released from active duty in the U. S. Army, has begun work as a physical metallurgist in the nonferrous division at Battelle Memorial Institute, Columbus, Ohio.

David Charles Miller has been transferred from Philadelphia to Pittsburgh to represent the scientific division of the Harshaw Chemical Co. in the sale of laboratory chemicals and apparatus.

A. W. Grosvenor, head of the department of metallurgical engineering of Drexel Institute of Technology and consulting metallurgical engineer, has been named the Delaware Valley Metals Man of the Year. This award is sponsored by the Philadelphia Chapter in recognition of major accomplishments in the field of metallurgy.



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Digests of Important Articles

Sand Mold Penetration Testing

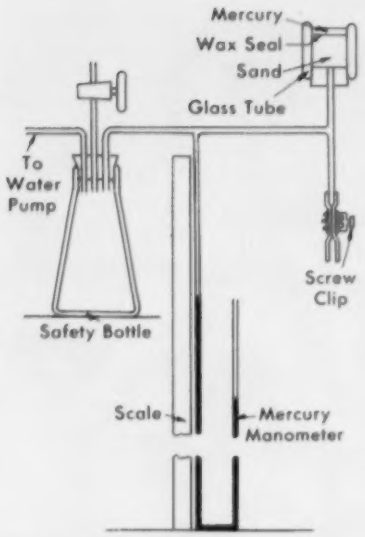
Digest of "Sand Mold Penetration Testing", by D. H. Houseman, D. V. Atterton and T. P. Hoar, *Metallurgia*, Vol. 53, January 1956, p. 21-25.

THE USUAL methods of testing resistance of rammed sand molds to penetration by molten metal are the indentation hardness tester for green sand molds and the scratch tester for dry molds. Both lack sensitivity and the results can be misleading when sand quality varies or when tests are not made immediately after the mold is rammed.

A simple room-temperature test which measures the pressure required to induce mercury to penetrate a sample from the mold face has been devised and has overcome the shortcomings of other penetration testers. The essential components of the apparatus are indicated in the diagram.

A cylindrical sand sample is taken from the mold, sealed in a glass tube and covered with a layer of mercury. The bottom of the tube is connected to a water pump and manometer, and suction is applied. When the mercury penetrates the sand, a reading is taken on the manometer. The pressure is compared with values for standard rammed compacts and indicates the degree of ramming of the mold. By simple conversion the approximate penetrating pressure of any other liquid metal can be calculated. Another calculation can be made to estimate the height of molten metal that the mold will withstand without penetration.

Test samples are removed from the mold face by inserting a 1-in. diameter cork borer to a depth of 1 in. and giving it a slight twist before withdrawing. The mold face



Apparatus for Measuring the Penetrating Pressure Required to Force Mercury Through a Sand Mold

can be patched to fill the resulting hole. Actual depth of sand removed is not important since penetration must occur through the surface. Standard samples of compacted sand are prepared in the same way from 2-in. diameter, 2-in. high A.F.A. standard sand test pieces.

The sample is placed, mold face upward, in the glass tube of the apparatus and sealed around the edge with paraffin wax. The seal should run about ¼ in. down the side of the compact. Mercury is put on the sample to a depth of 0.5 cm. An electrical circuit having contact probes and a lamp can be arranged to show when the correct depth has been reached.

Pure mercury cannot be used because increasing contamination alters its surface tension. It can be suitably conditioned by drawing repeatedly through a bentonite-bonded sand compact until the contamination level is stabilized.

A pressure difference across the mercury layer is built up by gradually evacuating the apparatus. At the critical pressure, mercury penetrates quickly and completely into the compacted sand. The pressure difference is read on the manometer when the electric circuit is broken. The mercury can be recovered by opening a screw clip at the end of the tube.

Checks of the technique show reproducibility to 0.5 cm. The maximum head of any molten metal that a mold will withstand can be estimated since it is directly proportional to the penetration pressure for the conditioned mercury. There is a conversion factor which is dependent upon the metal involved and the pouring temperature. It varies from 3.7 for molten tin to 8.0 for iron poured at 2910° F. A conversion factor of 8.0 is suggested as conservative for normal steel foundry practice where sintering of the mold surface is avoided by careful pouring procedure.

ARTHUR H. ALLEN

Effect of Temper Rolling on Strain Aging

Digest of "The Effect of Temper-Rolling on the Strain Ageing of Low-Carbon Steel", by H. P. Tardif and C. S. Ball, *Journal* of the Iron and Steel Institute, Vol. 182, January 1956, p. 9-19.

THE SEVERITY of the stretcher-strain markings in low-carbon steel pressings may be related quantitatively to the yield-point elongation. Normally, the yield point can be temporarily eliminated by temper rolling, roller leveling or stretching. For a given set of aging conditions temper rolling is the most efficient method of delaying the return of the yield-point elongation. This report describes a study of the aging process in mild steel after prestraining by stretching and temper rolling. Aging

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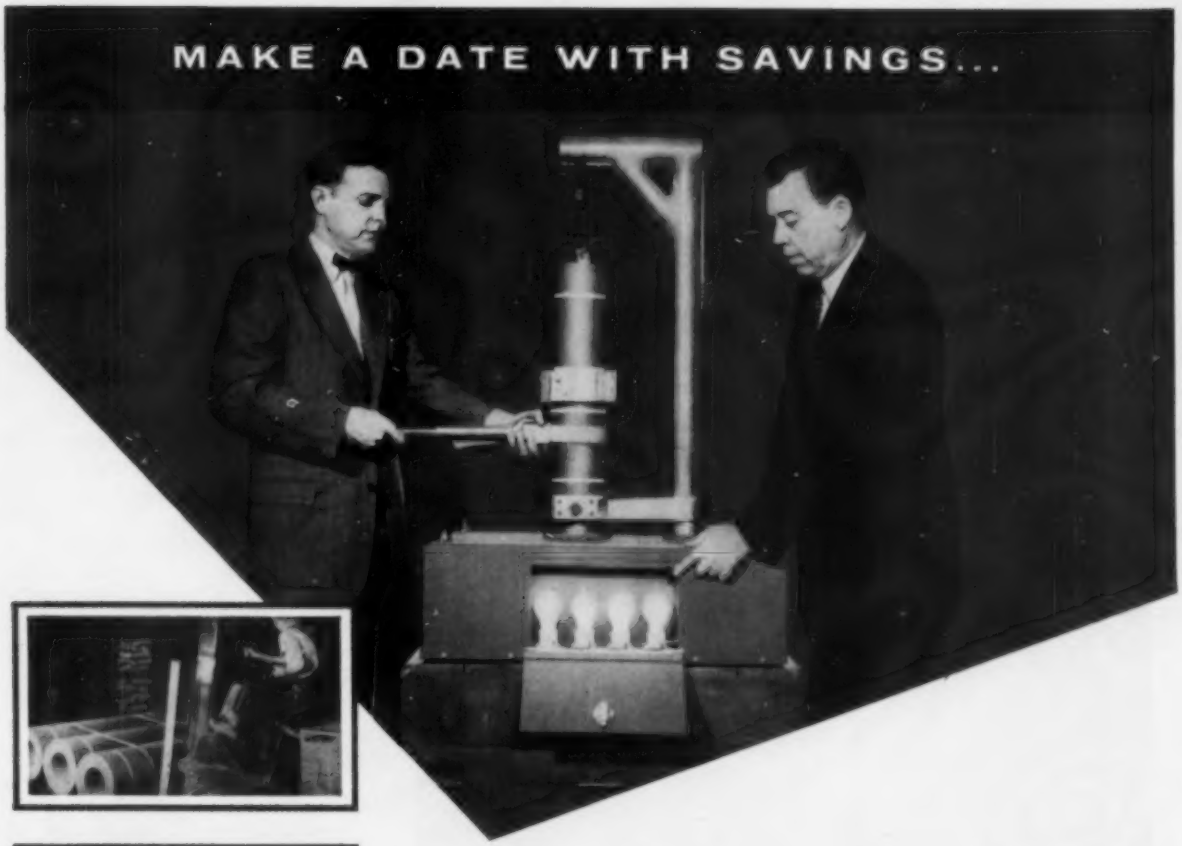

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Strain Aging . . .

was measured by studying the rate of return of yield-point elongation.

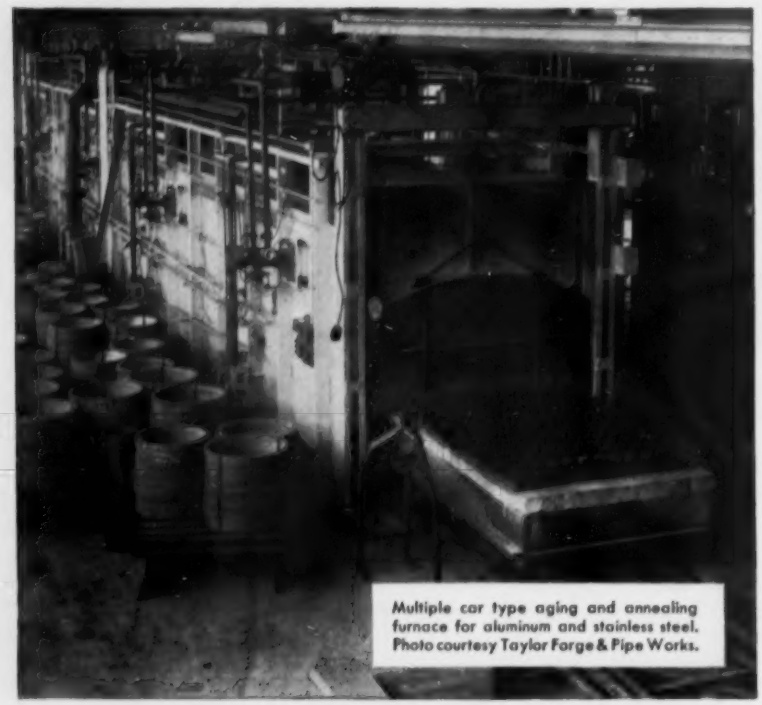
The material used for testing was deep drawing steel containing 0.053% C, 0.31% Mn, 0.028% S, 0.018% P, 0.005% N and a trace of Si. To eliminate quench aging all test pieces were annealed in a vacuum at 1560° F. for 4 hr. and furnace cooled. The rate of aging was studied after prestraining by either 5% tensile elongation or 3% reduction in thickness by rolling. The samples were aged for periods up to 100,000 min. at temperatures of 120, 150, 185, 210 and 240° F. in controlled oil baths.

Hardness tests showed no apparent difference in the rates of aging for temper rolled and stretched test pieces. Graphs of the activation energies made by plotting the log of aging time against the reciprocal of the absolute temperature showed a straight-line relationship in all instances whether based on hardness increase, yield strength or elongation at the yield strength. The activation energy values were 18,060 cal. per mole for temper rolling and 18,200 cal. per mole for stretching.

After stretching it was found that elongation returned to 50 to 60% of its value in the annealed condition in a short time and then there was a considerable delay before any additional increase took place. After this delay, the elongation continued to increase. Similar results were obtained with the temper rolled test pieces aged at 210 and 240° F. but the delay was of much shorter duration and was not so well marked.

The values of the activation energies agree with those of other workers and are of the same order as the values measured for the diffusion of carbon or nitrogen in alpha iron. The rate of return of the yield-point elongation appears to depend on the rate of diffusion of carbon or nitrogen. Within the range examined the mechanism that causes the yield-point elongation to return on aging is independent of the method of prestrain. The absolute measured value of the yield-point elongation does depend upon the method of prestrain.

The authors conclude that the same basic mechanism of aging operates in both temper rolled and stretched steel; that is, the increase in yield stress and hardness depends on the diffusion of carbon or nitrogen atoms to dislocations. The retardation of the return of the yield point elongation by temper rolling when compared to prestraining in tension appears to be related to the propagation of the yield throughout the test piece and the resultant strain hardening. Deformation by temper rolling is an inhomogeneous process and produces varying degrees of internal stress in the steel. The presence of such stresses whether acting over microscopic or macroscopic dimensions will initiate early yielding. Hence, yielding in the temper rolled sheet will not be sudden, but will take place progressively, at increasing applied stress values. As aging proceeds a greater number of dislocations become anchored and the effect of internal stress diminishes in a proportionate manner;



Multiple car type aging and annealing furnace for aluminum and stainless steel. Photo courtesy Taylor Forge & Pipe Works.

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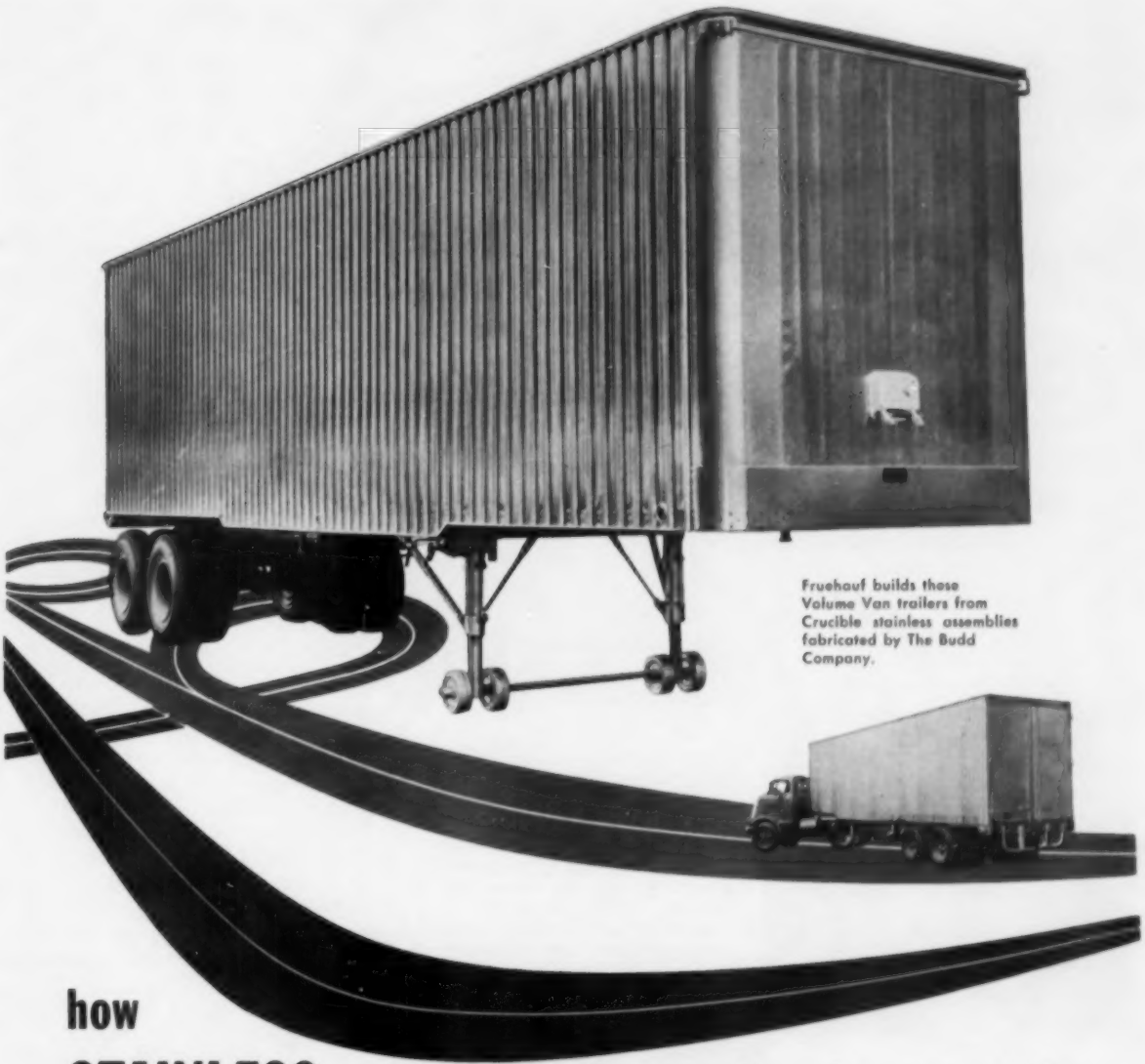

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Strain Aging . . .

however, the absolute value of the measured yield elongation is less than that measured on a stress-free test piece in which cataclysmic movement of dislocations may take place. Experimental results support the hypothesis that the influence of macroscopic body stresses is minor and that oriented microstresses have a much greater effect on the retardation of the return yield point.

W. A. MORGAN

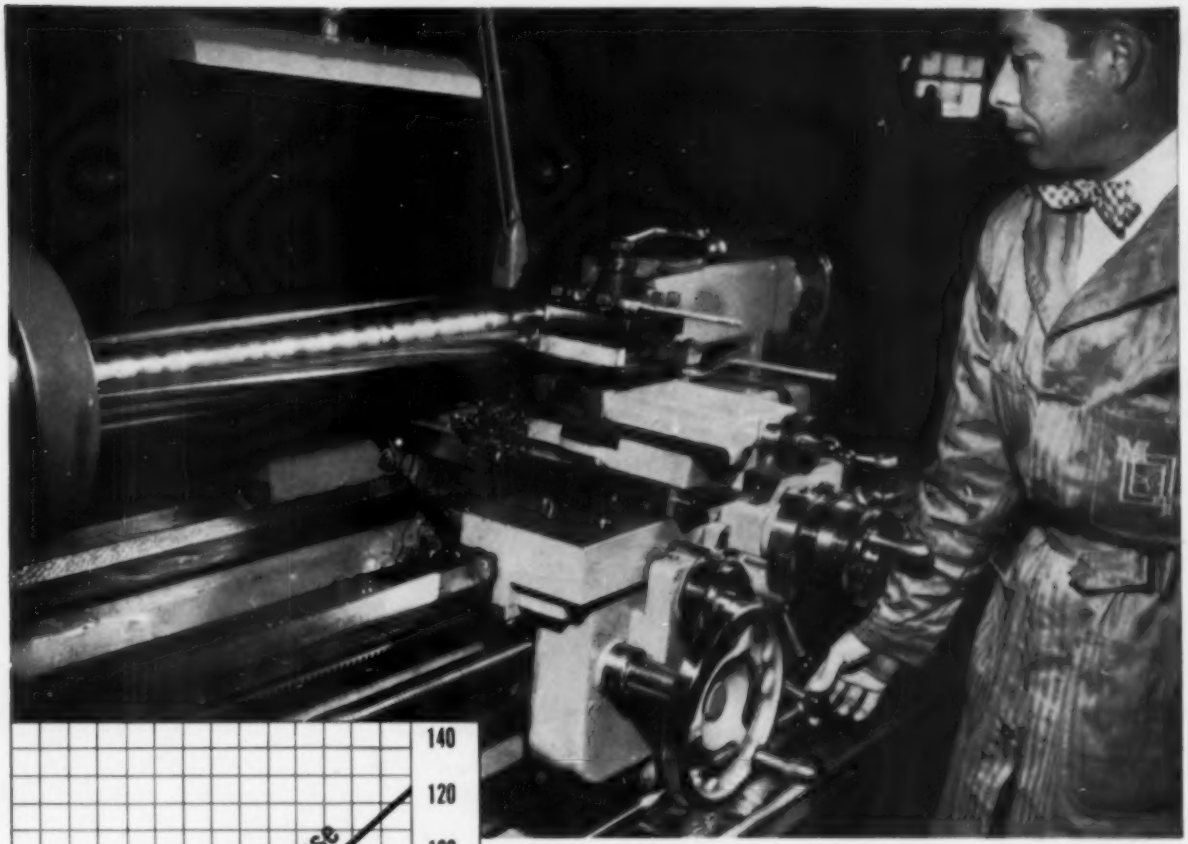
Iron and Steel for Marine Service

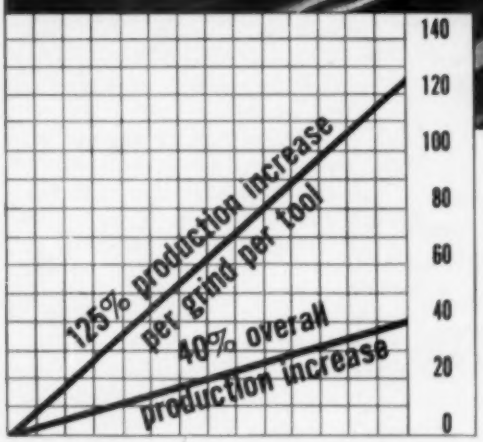
Digest of "Ferrous Materials in Marine Engineering", by S. F. Dorey, *Transactions* of the North East Coast Institution of Engineers and Shipbuilders, Vol. 72, November 1955, p. 27.

MARINE engineers prefer to use time-tested materials for construction because even a minor structural failure might render a ship powerless or even cause it to sink. Unfortunately the increase in severity of operating conditions has made it necessary to switch to stronger and more corrosion resistant alloys. The major problem associated with the use of the newer cast irons and steels is evaluation of their corrosion, erosion and abrasion resistance in marine service.

Cast iron is the ferrous material most widely used for propellers. To save weight, low-alloy nickel and molybdenum irons have been adopted in recent years. Propellers for ships which navigate in ice are usually made of low-alloy steel. Swedish engineers now consider a 13% Cr, 1% Ni, 1% Mo steel the best for propellers because of its excellent resistance to corrosion and cavitation erosion. Austenitic stainless steels have been used but cost more.

Plain carbon steels are used for thrust, gear, intermediate and propeller shafts. Most are made from 0.25% carbon steel forgings normalized to strengths of about 65,000 psi. To save weight, the use of 0.45% carbon steels with strengths up to 85,000 psi. is increasing. Outboard and inboard screw shafts on several aircraft carriers were made from a 3.7% Cr, 2% Ni steel. Because of a corrosion-fatigue failure of one outboard





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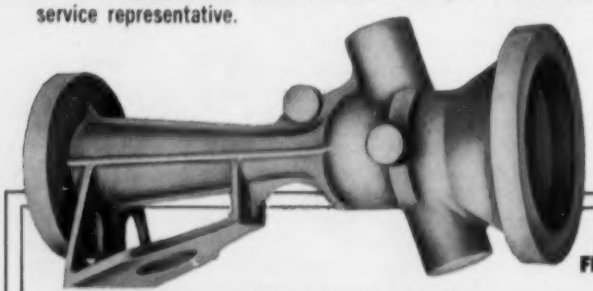

DESIGN FLEXIBILITY

Parts similar to this stainless steel valve body for an air flow controller often require several changes before design is finalized. Due to the relatively low cost of dies and die changes, the investment casting process has proven an inexpensive and flexible method.

ARWOOD

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"PIONEERS IN INVESTMENT CASTING"

Marine Service . . .

shaft, the steel is now used on inboard shafts only. Reverting to a lower alloy steel made it necessary to increase the shaft diameter from 21 to 28 in. Shaft diameters cannot always be reduced by substituting higher strength steels because rigidity is important. For similar working stresses, the section and rigidity are smaller for alloy steel shafts.

The increasing use of high-strength cast irons for the crankshafts of marine engines and pumps is attributed to encouragement by the U.S. Navy. Low-molybdenum and nickel-molybdenum cast irons are most widely used. Forged crankshafts larger than 10 in. in diameter are usually made from normalized 0.25% carbon steel but in faster engines where power-to-weight ratios are more important, normalized 0.40% carbon steels with ultimate strengths of 78,000 psi. are used. Where greater toughness is necessary, steels containing about 1% of nickel, manganese or chromium are often specified.

Rotor shafts of marine steam turbines usually operate below 800° F. where medium-carbon steels have adequate creep strength. Carbon-molybdenum steels are used for operating temperatures up to 950° F. in British installations. The trend is to the molybdenum-vanadium steels for temperatures between 900 and 1050° F. These alloys are more resistant to embrittlement from long service at elevated temperatures.

Most marine turbines operate with steam temperatures below 900° F. and the turbine blades are usually made from low-carbon 13% chromium steels with 0.5% molybdenum. Carbon contents of 0.15 to 0.20% are considered suitable for operation in superheated steam. Steels with 0.09 to 0.14% carbon are preferred for operation in moist steam and for weldments. The higher operating temperatures of new turbines have made it necessary to use 18-8 Cr-Ni austenitic steels for turbine blades. The austenitic steels have better creep resistance but necessitate some modifications in design and manufacturing methods.

Stress-corrosion cracking of mild steel plates in riveted seams of cylindrical boilers is still a problem. Such

INTRODUCING GRAPH-AIR...

a tougher, more versatile graphitic tool steel that air-hardens at temperatures 200° to 300° lower with less distortion!

NO facilities for oil-quenching—or other relatively costly heat treating processes? Need a finer air-hardening tool steel? Then specify *Graph-Air,* newest steel resulting from the Timken Company's pioneering in fine alloy steels. Latest addition to our line of quality graphitic tool steels!

Graph-Air tool steel air-hardens at temperatures of 1450°F to 1550°F—200° to 300° lower than most other air-hardening tool steels. And because Graph-Air *is* air-hardened, there's less distortion, easier heat treating control, less decarburizing. As a result, Graph-Air can be made into *more intricate sections.* Graph-Air is a tough air-hardening steel, too—made to order for such demanding applications as blanking dies, or any tool steel part which must take hard abuse.

Besides all the advantages of air-hardening—economy, less drastic reactions to quenching, less tendency to scale—Graph-Air offers greater wear, machinability and stability. Like Graph-Mo, Graph-Air will outwear other tool steels, because of the uniform diamond-hard carbides in its structure. And Graph-Air machines 30% faster. The free graphite in its structure acts as a built-in lubricant. And Graph-Air stays *accurate longer,* is fully as stable as other Timken Company graphitic tool steels, which are the most stable tool steels made!

Growing out of the Timken Company metallurgists' long experience with fine steel making, Graph-Air—the *new* graphitic tool steel that can be air-hardened at *low* temperatures—will be available in both solid and hollow bar sizes. For more information, write: The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

TIMKEN *Fine Alloy* **STEEL**

TRADE-MARK REG. U.S. PAT. OFF.

SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS STEEL TUBING

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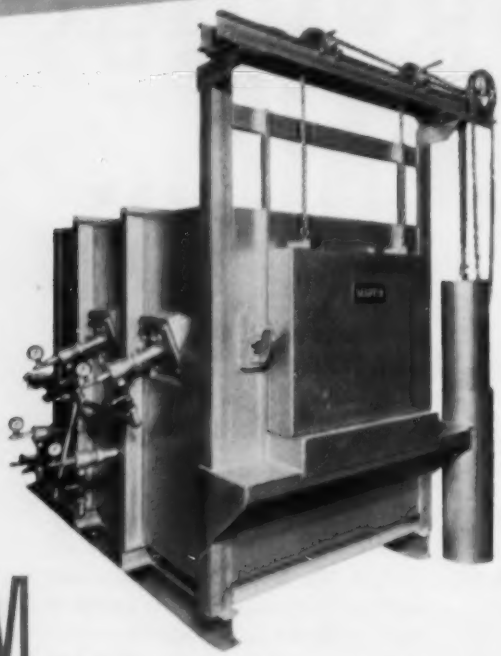

MARTIN furnace shown was built for a leading manufacturer of aircraft engine parts. Advanced in basic design, it also incorporates several features which our customer felt certain from long experience would do their job better . . . and faster. As anticipated, this furnace is now out-performing all others on Nicro-brazing operations, at temperatures up to 2500° F.

Why not ask this defense contractor?*

You, too, may have some furnace ideas that will do your job better and faster. Write us today for information on building a MARTIN advanced design furnace to your requirements.

* Name and details upon request.

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ADVANCED DESIGNS IN ALL TYPES OF FURNACES

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MARTIN MANUFACTURING CO. | 10 EMERY STREET DETROIT 3, MICHIGAN

Marine Service . . .

failures can be minimized by treating the feed water and by using fully killed medium-carbon steels relatively high in aluminum.

Until recently boilers and steam pipes have been designed for working stresses less than one-fourth of the tensile strength. Since the war, however, the Germans have made both carbon and alloy steel drums with wall thicknesses 20 and 30% less than those corresponding to the common safety factor. The German standards for steam boilers permit factors of safety ranging down to 2.43 for alloy steels and 2.83 for carbon steels. Engineers in other countries are interested because thinner plates simplify manufacture and reduce costs. Welding difficulties and troubles caused by alloy segregation are less pronounced in thinner plates.

F. W. BOULGER

Blast Cleaning Variables

Digest of "The Blast Cleaning of Metal Surfaces", by Otto Peltzer, *Stahl und Eisen*, Vol. 75, December 1955, p. 1681-1691.

BLAST cleaning was first developed in 1870 by Gen. Benjamin C. Tilghman of the United States Army. He discovered that metal, stone or glass surfaces could be etched by a jet of sand. The first blast cleaning machine used a steam jet and sand. This had many disadvantages, one of which was the need to dry the sand. General Tilghman's idea was adopted by others and one development that followed naturally was a machine in which the sand could circulate during the operation. The use of metallic media was introduced in 1920 in the form of white iron grit. Its short life led to the use of heat treated steel grit and later fragments of steel wire.

Modern-day blast cleaning processes can be divided into five major groups:

1. Sandblasting—Dry silica sand is hurled against the surface by compressed air. This is used where it is uneconomical or impossible to reuse the material.

2. Wet Sandblasting—Silica sand is mixed with water and forced at

XVI

This is the sixteenth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Copper: Its Principal Effects in Alloy Steels

One of the best known of all metals, copper certainly needs no introduction here. Its uses are legion. It is one of the best conductors of heat and electricity. It is popular with the housewife, essential to the engineer. But possibly not so well known is its very important function as an alloying element in certain types of steels. So used, copper increases resistance to atmospheric corrosion and also acts as a strengthening agent.

Since copper does not oxidize in the steel melt, it can be added at any time during the course of the heat. Pure copper melts at about 1980 deg F.

Copper is added to steel in varying amounts. The actual proportion, of course, depends upon the end product in mind. Some of the most widely used copper-bearing steels are those containing from 0.20 to 0.50 pct. In these, copper has been found to increase corrosion-resistance without materially affecting mechanical properties. It has been found, too, that paint frequently lasts longer on such steels than on the non-copper-bearing types.

Among the best known of the copper-bearing steels are the high-strength, low-alloy grades developed in recent years. Generally speaking, the ductility of steels in this group is comparable to that of conventional structural steel. The yield strength, however, is usually higher. Copper, working as a team with chromium, nickel, and phosphorus, substantially raises the level of corrosion-resistance in these steels; yet its presence does not adversely affect welding characteristics.

Copper-bearing steels are a subject in themselves, a subject in which Bethlehem metallurgists are well versed. If you would care to know more about this interesting group of steels, feel free to consult with our technicians. They will gladly work closely with you and help with any problems you may encounter. And please remember, too, when you need alloy steels of any kind, that Bethlehem manufactures the full range of AISI standard alloy grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this entire series of advertisements, Nos. I through XVI, please write to us, addressing your request to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. The material is now available in a convenient 32-page booklet, and we shall be very glad to send you a free copy.

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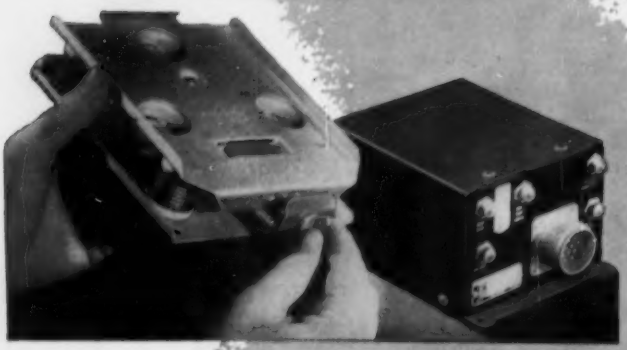
ALLOY WIRE Cushions...



take the SHAKES out of AIRCRAFT INSTRUMENTS

Fabricated all-metal mounts have high damping properties . . . Resist deterioration.

Robinson Aviation, Inc., Teterboro, New Jersey, uses knitted stainless steel and nickel alloy wire cushions in their new all-metal engineered mounting systems to control vibration and shock in airborne electronic equipment and instruments. Alloy wire resilient cushions have attained performance standards heretofore impossible with conventional rubber or synthetic materials.

When fabricated into a special pattern, the wire forms literally thousands of tiny interlocking springs. Their high damping characteristics and non-linear spring rate provide ample protection against dynamic overloads. Alloy wire resists deterioration by oil, water, ozone, bacteria, dust and extreme temperatures. Knitted alloy wire is used in hundreds of other industrial applications, such as filters, mist eliminators, electronic shielding. For further information send today for our Application Bulletin A-1.

ALLOY METAL WIRE DIVISION

HKP H. K. PORTER COMPANY, INC.
Prospect Park, Pennsylvania

Blast Cleaning . . .

the surface with compressed air. This method is used in shipbuilding where ships' hulls or other large surfaces are to be cleaned and also in other industries where dust must be avoided.

3. Shot and Grit Blasting—Round and angular metal particles are propelled at the surfaces by compressed air or centrifugal force. This is used for removing scale from rolling mill products. The finish obtained is suitable for galvanizing, enameling, phosphatizing or painting.

4. Hydro Sandblasting—A mixture of coarse silica sand and water is forced at pressure of about 1700 psi. against the surface to be cleaned.

5. Liquid Jet Cleaning—Fine silica sand is added to water and forced by compressed air or pumps at a pressure of 45 to 85 psi. to produce very fine surfaces on tools, dies and similar pieces where surface finish must be exceptionally smooth. Cleaning efficiency can be obtained by blending a harder material such as rice hulls with one of the softer mediums.

Most blast cleaning materials are either round like shot or irregular and angular like grit. Shot is usually used to remove molding sand and scale, whereas grit is most commonly used to remove paint or rust. The particle size must be considered in relation to the shape of the pieces to be cleaned. Since large grains of shot rebound from the surface, they are best suited for complicated shapes. The large particles rebound and strike relatively inaccessible areas before their kinetic energy is completely dissipated.

The particle size of the shot or grit is governed by the thickness of the parts that have to be cleaned. Thin pieces may be worked too severely or even damaged if heavy particles are used. The particle size also affects the surface condition. Finer surfaces are obtained with smaller particles. Particle size must be controlled because an excessive amount of fines may produce a drastic increase in cleaning time. In addition to screening out fines it is necessary to remove all foreign material such as particles of scale or metal.

R. C. SHNAY

New improvement in Chromium Plate

New plastisol sprays coating 60 mils thick

Unichrome "Super 5300" Coating delivers the full solids content of vinyl plastisol right through a spray gun. It permits a pore-free 50 mil coat to be obtained in just one application on flat or irregularly shaped surfaces.

Single or multiple coats of this material amount to a vinyl "sheet" material, but *without* any seams or joints where corrosives might penetrate. "Super 5300" shrugs off strong acids, caustics, water, salt solutions and other corrosives. Its heavy duty protection often permits use of ordinary metals in place of costly alloys. Write in for more data.

Good masking with non-cyanide copper plating

Metals engineers have long made good use of Unichrome Pyrophosphate Copper Plating Process for stopping off areas in nitriding and carburizing. Because of the density and fine grain of the deposit, dependable masking is secured with a thinner plate, saving time, money and copper. Bulletin CU-3 tells more.

METAL & THERMIT CORPORATION

General Offices: Rahway, New Jersey
Pittsburgh • Atlanta • Detroit
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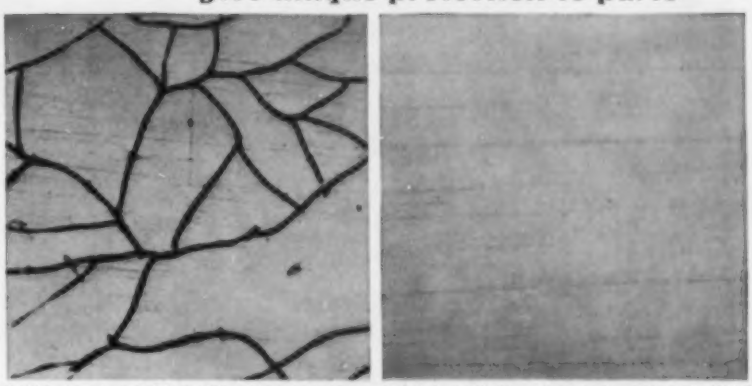
Metal & Thermit—United Chromium of Canada, Limited, Toronto

Crack-Free Chromium Deposits give unique protection to parts



(Left) Surface view of etched ordinary chromium surface, enlarged about 75X, shows typical network of cracks. (Right) Etched Crack-Free Chromium surface shows none of this. Steel parts are therefore securely protected from rust.

Electrodeposits become continuous surfaces as thickness increases and porosity vanishes . . . except for *ordinary* chromium plate. Something else happens. Cracks develop as the chromium deposit builds up. Through these defects, corrosives reach the underlying metal. Unichrome Crack-Free Chromium eliminates these structural imperfections.

Comparative tests have demonstrated that Crack-Free Chromium makes a tremendous difference in corrosion protection.

At 110° F, and 100% relative humidity, only .0003" of Unichrome Crack-Free Chromium protected steel from rust for over 1000 hours. With ordinary chromium, identical parts were rust-covered in just *days*. In testing protection of .0005" of chromium plate in salt spray for 100 hours, one user found steel shafts protected with Crack-Free Chromium unaffected; while shafts with ordinary chromium were enveloped with rust.

WHERE TO USE

That is a question best answered by product designers. Knowledge of the complete advantages may suggest many uses. Crack-Free Chromium also offers:

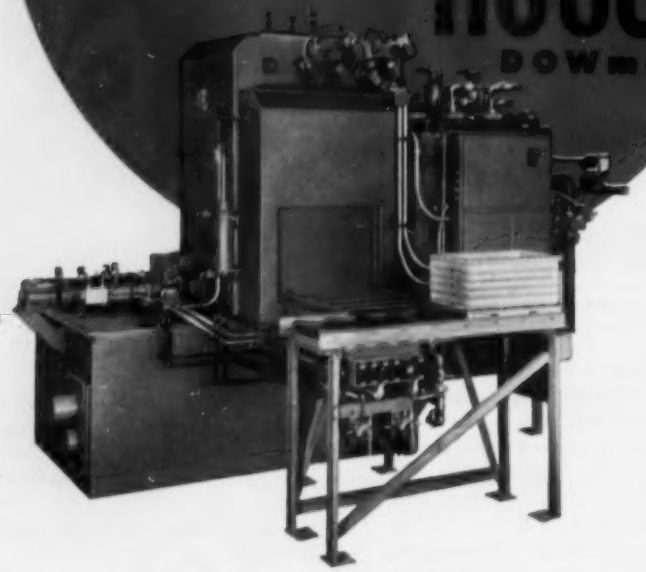
1. Wear-resistance, hardness, and low friction.
2. Improved non-galling, non-seizing properties.
3. A more ductile deposit, resistance to thermal shock and better protection at elevated temperatures. Good impact resistance.
4. Excellent leveling action which helps cover surface imperfections. Also easier, faster grinding, if required.
5. Protecting the base metal without undercoats, Crack-Free Chromium can be used directly on steel or zinc base die castings for many applications.

APPEARANCE

A satin, matte finish, Crack-Free Chromium can be left as is, or readily buffed to high luster. Ask for recommendations, or send for Bulletin CFC-1.

FINEST AUTOMATED BATCH-TYPE CONTROLLED ATMOSPHERE FURNACE— THE HC-800

DOWmatic



All the proven advantages of DOW'S top quality controlled atmosphere, furnaces with built-in atmosphere generators . . . PLUS time saving automation in one compact, efficient package.

This new furnace pre-conditions, loads and unloads the work chamber, quenches the charge and discharges the finished work without operator handling.

No time loss, no guessing, no human error . . . every load identically processed and handled.

Write for detailed literature.

DOW FURNACE COMPANY

12045 Woodbine Ave., Detroit 28, Mich.
Phone: KEnwood 2-9100

First WITH MECHANIZED, BATCH-TYPE, CONTROLLED ATMOSPHERE FURNACES

Criticism of Engineering Education

Digest of "A Criticism of the Technical Education of Recently Qualified Engineers", by P. P. Love, *The Engineer*, Vol. 200, Nov. 18, 1955, p. 737-740.

MR. LOVE criticizes the present graduates in the sciences and technology as having a fund of factual knowledge but an inability to use this knowledge to solve industrial problems. Several hypothetical examples are cited in which one engineer arrived at a solution through standard cookbook methods, while another engineer faced with the same problem first decided exactly what was wanted and then developed an unconventional program which produced a solution in much less time and at less cost.

One of the problems was to design a broach blade to give the longest life within a limited range of cutting speed in broaching a flat surface accurately. The first engineer laid out a program in which each factor, such as tooth pitch and step, tooth land and rake angle, was varied one at a time. Not all of the experiments were completed but had they been, some 800 hr. would have been required using 16 sets of broaches at £60 per set and 480,000 pieces, and many of them would have been scrapped during the experiment.

The second engineer simulated the problem with a lathe and single point tool, "facing" the end of tubing the same thickness as the material to be broached. The tube was slotted to give an interrupted cut as in broaching. With a single-point tool, chip action could be studied clearly and the tooth shape modified much more readily. It was observed that at low speeds there was a significant interaction of rake, step and shear angles which would not have been observed in the conventional kind of experiments. The second engineer arrived at a solution in about 200 hr. using only six single-tooth tools at a cost of £3 each and 20 ft. of 3-in. diameter tube. He used no knowledge outside the certified range of the conventional engineer. The other examples described are similar in that the first engineer proceeded without a well-planned

Operation Deepfreeze sleds plow across Antarctica on tough skis of USS "T-1" Steel

IGY IS THE REASON. Scientists with the current Navy expedition to Antarctica will obtain scientific data on weather, atmospheric conditions, aurora and air glow, glaciers, geomagnetism, and allied subjects during the next International Geophysical Year (1957 and 1958). Tractor-drawn trains of cargo sleds, built by Otaco, Limited, Orillia, Ontario, Canada, will be used to haul supplies. Skis for the sleds are made of USS "T-1" Steel.

THE SKIS ARE MADE OF USS "T-1" STEEL. When the going gets rough, the runners on these cargo sleds are assembled into skis, 13 feet long and 34 inches wide, made of USS "T-1" Steel.

DURING OPERATION DEEPFREEZE, the Navy's current expedition to Antarctica, thirty-eight rugged cargo sleds will be used to haul supplies 400 miles from Little America to Marie Byrd Land. The 11-ton sleds, each carrying a load up to 20 tons, ride on skis made from tough ¼" plates of USS "T-1" Steel. The sleds were designed jointly by the United States Navy and Otaco, Limited, Orillia, Ontario, Canada.

Naturally, the skis had to be made from a steel that stays tough and durable at temperatures far below zero. The steel also had to possess high strength (to keep down weight), and excellent resistance to abrasion (to withstand the 400-mile trip across rugged, ice-covered terrain). In addition, the steel had to have good forming characteristics and be easily weldable (to simplify fabrication).

One steel met all the requirements; that was USS "T-1" Steel. USS "T-1" Steel has a minimum yield strength of 90,000 psi . . . can be welded as easily as carbon steel, with the proper electrodes . . . has excellent resistance to abrasion and impact abuse . . . and remains tough at low temperatures. It was ideal for this tough job.

A VERSATILE NEW ALLOY STEEL

USS "T-1" Steel is adding strength and durability, cutting weight and costs, in steel mill equipment, power shovels, mine cars, bridges, coal handling equipment, pressure vessels, and many other applications, at high and at low temperatures. It probably can help you improve your own product. Write for complete information. United States Steel, Room 5353, Pittsburgh 30, Pa.

UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
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USS "T-1" CONSTRUCTIONAL ALLOY STEEL

USS

See The United States Steel Hour. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

UNITED STATES STEEL

Take surface temperatures quickly, accurately... with the

Pyrocon

The handy Alnor Pyrocon is unequaled for quick, accurate reading of all surface temperatures . . . whether they are metallic or non-metallic, flat or curved, stationary or revolving. Accurate temperatures are easily understood on the Pyrocon's direct reading scale face . . . without interpolation or need of conversion tables. A wide selection of thermocouples and extension arms permits adaptation to many types of service. For complete details and prices, send for Bulletin No. 4257. Illinois Testing Laboratories Inc., Room 523, 420 N. LaSalle Street, Chicago 10, Ill.

Alnor

PRECISION INSTRUMENTS FOR EVERY INDUSTRY

Education . . .

course of action while the second first determined exactly what the problem was and investigated only the variables which were significant.

Mr. Love's major point is that in the schools there is a marked deficiency in instruction in using the mind. He believes, and cites supporting references, that "skill in using the mind can be assisted and speeded up by knowledge of certain techniques in thinking". In his experience with college graduates, however, none that he questioned had had any instruction in how to think. He points up the deficiency with reference to the usual examination questions in which most of the thinking has been performed by the examiner in devising the questions. He feels that most examinations grade the ability of the student to put down on paper knowledge of a subject such as any plodder could acquire if granted sufficient time.

The editor of *The Engineer* questions whether too much emphasis is not being placed on the teaching of fundamentals. With the widening of the boundaries of technology, the modern syllabus is strained to the limit even when limited to the fundamentals. Hence the syllabus is based on the type of examination to be given and, in general, the examinations have come to require merely the relating of factual knowledge.

The fundamental need in education is not really that of providing knowledge but of teaching students how best to make use of the brains with which they have been endowed. The editor and Mr. Love, as well as other contributors, have the impression that the engineering syllabus has become so overweighted with "fundamentals" that this aim of teaching students to think is in danger of being forgotten.

Engineering boundaries are widening so rapidly that one would hesitate to predict what sort of industries will exist 40 years hence. It is likely that many of the "fundamentals" now considered essential will not be required at all. It is suggested that there be a severe "root-pruning" of the teaching of fundamentals and much more attention should be paid to developing a specific training in thinking.

A. J. Smith

Nonferrous Melting with . . .

SPENCER
HARTFORD

TURBO-COMPRESSORS

There are many methods of melting non-ferrous metals but the accepted standard for furnishing air to Oil and Gas fired furnaces is the Spencer Turbo-Compressor. A battery of Spencer 5 HP turbos in the foundry of a large Chemical plant is shown below.

Thirty-five years ago the Spencer Turbo was first specified by a furnace manufacturer. Today it is the first choice of all of the leading furnace and oven manufacturers.

The reasons they prefer Spencer are the absolute reliability—perfect performance and low maintenance over long years of almost continuous service. Spencer Turbos range in size from 35 to 20,000 cu. ft. per min., 4 oz. to 10 lbs. and 1/3 to 1,000 HP.

For complete description of the standard and special Turbos ask for Bulletin No. 126-A.

THE SPENCER TURBINE COMPANY

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Manufacturers of Turbo-Compressors and Heavy Duty Vacuum Cleaners

IT'S A **BETTER MOLD**
IT COST **30% LESS**
CAST TO SHAPE IN
DARWIN & MILNER PRK·33
TOOL STEEL

Large ring is 30" in diameter, 2¾" thick.

• The S. K. Wellman Company, Bedford, Ohio, leading maker of all metal clutch plates, facings and brake linings, had traditionally bought tool steel forgings for these mold parts until they tried PRK-33 Air Hardening Cobalt, High Carbon, High Chrome castings.

The results were completely satisfactory. The cost was 30% less than forgings. The castings were closer to final dimensions than the forgings and were much easier to machine.

Because PRK-33 is a higher grade steel than that previously used in the molds, runs between grinds were at least equal and often longer.

If you use tool steel molds, dies or tools—call or write now! We can advise you how "Cast to Shape" may be able to offer you a substantial savings in your tooling.

Complete line of highest grade Tool Steels, including PRK-33, DARWIN No. 1, NEOR, MINEOR, OHT, "MT6" and various grades of Hot Work Specialty Steels. Furnished in Bar Stock, Billet and Sand Casting, Drill Rod, Flat Ground Stock and Tool Bits. Bulletin on Request.

DARWIN & MILNER Inc.
highest grade tool steels
2345 ST. CLAIR AVENUE ★ CLEVELAND 14, OHIO
• 1810 W. FIRST AVENUE • COLUMBUS, OHIO •

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Spot Weld Failures Analyzed

Digest of "The Behavior of Spot Welds Under Stress", by J. F. Rudy, R. B. McCauley and R. S. Green, *The Welding Journal*, Vol. 35, February 1956, p. 65 s-71 s.

A NEW method of testing spot welds called the "sectioned spot shear test" uses a specimen cut through a spot weld in such a way that a section through the middle of the weld is exposed on the lengthwise edge of the test specimen. The edge of the specimen showing the spot weld is polished and etched and the effects of increasing stress on the microstructure may be observed.

The failures encountered in the tension-shear tests of the spot weld specimens are of three types: shear, in which the fracture is approximately parallel to the contact surface of the welded sheets; tears, which are perpendicular to the surface and outside the weld; and intermediate, which start as shear but end in a tear. In low-stress shear failures there is no deformation of the base metal. Where the weld strength is greater the fracture passes through the base metal with some deformation. The sectioned spot shear test indicates that solid-phase grain growth across the contact surface is more complete in the stronger welds because of the application of more heat in welding.

In failures of intermediate type, the weld buttons are at least partially torn out of the plate. In such failures at low stress levels, plastic strain occurs first along the contact surface between the welded sheets. At higher stress it avoids the stiffer nugget and passes around the weld causing the nugget to pull away.

In tear failures where all the fractures are tensile there is only a very short distance between the weld edge and the nugget, and plastic strain is confined to that small area. In such welds the nuggets are so large that the usual 45° slip in the base metal is interfered with and failure of the sheets occurs in tension rather than shear.

In all three types of failures the initial stress causes strain at the weld edge. In the shear type the deformation continues through the weld. In

Braze it for 4¢ with TOCCO*

Willey's Carbide Tool Company, Detroit, reports the following benefits from TOCCO *Induction Brazing* of tool tips:

1. *Large lathe tools:* **8 times as fast.** *TOCCO brazes 85 per hour; former method 80 per day.*
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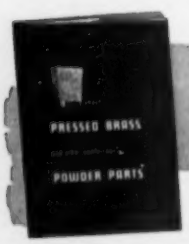

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Spot Welds . . .

the intermediate type it changes direction to pass around the nugget after passing partly through the weld. In the tear type it misses the weld. The weld strength varies inversely to the strain at the contact surface.

Fractures of the shear type occur only when the welding current is so small that no nugget with cast structure is formed. When the nugget occupies more than about 80% of the weld bond, all fractures are of the tear type. Between 0 and 80%, the fractures are intermediate. Thus the nugget development is an important factor in the type of failure and the strength of a spot weld. The sectioned spot shear test for spot welds gives valid indications of the effects of stress and is useful for correlating such effects with the microstructures.

G. F. Comstock

Stress-Corrosion of Stainless Boilers

Digest of "Stress Corrosion of Austenitic Stainless Steels in High Temperature Waters", by W. Lee Williams and John F. Eckel, *Journal* of American Society of Naval Engineers, Vol. 68, February 1956, p. 93-104.

Stress-corrosion cracking has occurred in equipment made of austenitic stainless steel when exposed to high-temperature water and the steam phase of such water. Although the stress-corrosion mechanism is believed to be the same in both steam and water phases, several variables may affect the results obtained in a steam-water system. For example, the effect of inhibitors may vary from the water to the steam phase, the oxygen concentration may vary in the two phases and dissolved solids can become highly concentrated on material exposed to the steam phase.

In high-purity water containing dissolved oxygen, hot rolled and mill annealed material rarely cracks from stress-corrosion. Heavy cold work increases its susceptibility to attack and subsequent annealing is not a reliable method of removing the cracking tendency. The presence of chlorides in naval boiler waters is

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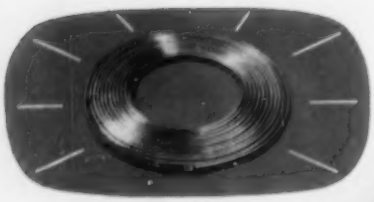

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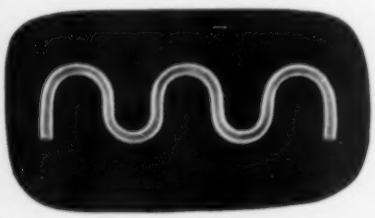

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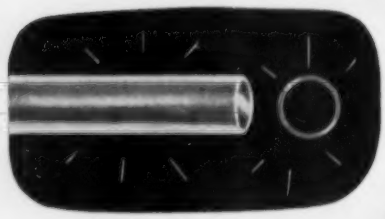

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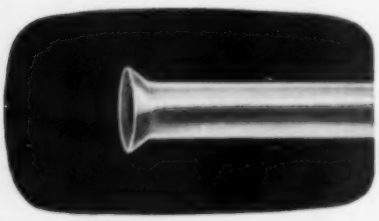

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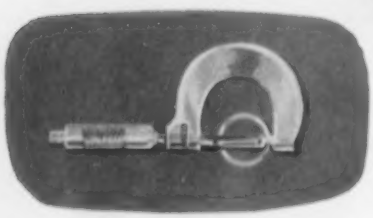

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Stress-Corrosion . . .

the most important factor leading to the stress-corrosion failure of austenitic stainless steels but oxygen content is also important.

If oxygen is present in plain chloride waters, cracking will occur on specimens in the water phase at temperatures nearly as low as the atmospheric boiling point and at chloride levels as low as 300 ppm. Cracking can usually be inhibited in boiler water if the water is treated with alkaline phosphate. Stress-corrosion cracking occurs in the steam phase when intermittent wetting takes place. This susceptibility to stress-corrosion is dependent upon the oxygen and chloride concentration of the system. The maintenance of oxygen at some concentration below 1 ppm. prevents stress-corrosion at chloride levels usually encountered in steam generation equipment. Treating of the water with alkaline phosphate does not prevent cracking in the steam phase.

Tensile stresses are necessary to cause stress-corrosion cracking. These stresses include applied stresses as low as 5000 psi. or residual stresses from tube rolling, joint welding and surface abrading with emery paper. Attempts to eliminate stress-corrosion cracking in the steam phase by the use of inhibitors such as tannin, chromate and octadecylamine have not been successful. Oxygen scavengers, such as hydrazine and sodium sulphite, added to the system, have a tendency to reduce stress-corrosion cracking.

Laboratory tests indicate that the austenitic stainless steels are more vulnerable to stress-corrosion when subjected to the steam phase of boiler systems where intermittent wetting is apt to occur. An example is at tube-header joints of heat transfer equipment. The prevention of crevices at these joints would aid in the control of stress-corrosion. Chloride and oxygen elimination are other methods of control. Stress-corrosion cracks nearly always start at macroscopic corrosion pits in the surface of the specimens. Therefore, pitting may be a necessary step in the initiation of the cracks.

The authors point out the need for extreme caution in the design and operation of equipment employing austenitic stainless steels in con-

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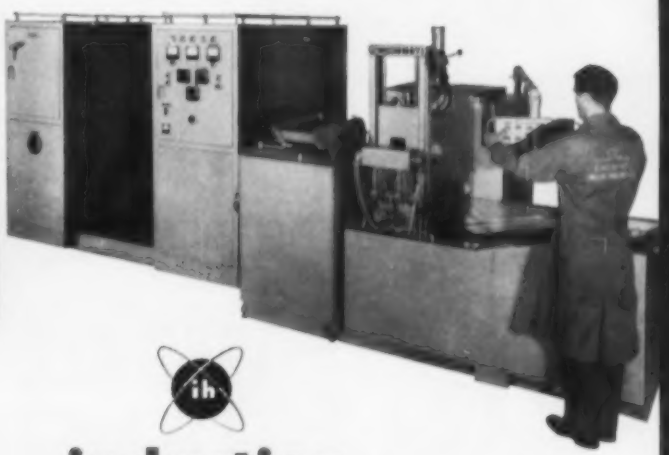

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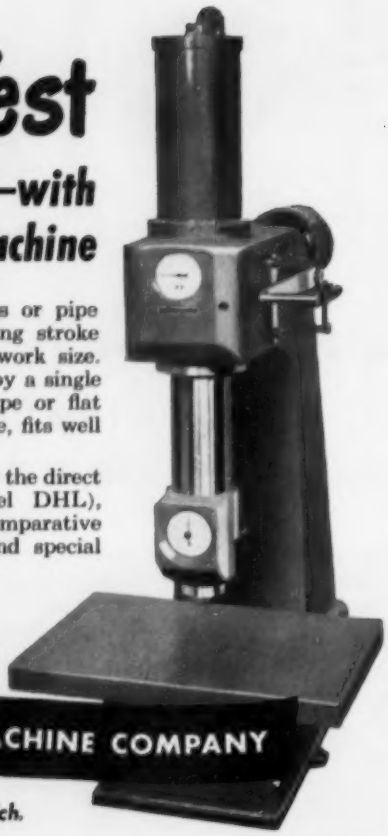

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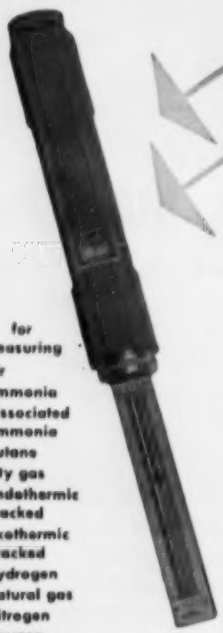

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Stress-Corrosion . . .

tact with high-temperature water and particularly the steam phase of the water.

They recommend the use of annealed and stabilized steels, stress relief treatment, low operational stresses, low chloride levels, low oxygen levels and proper corrosion inhibitors as important steps in eliminating the hazards of stress-corrosion cracking.

F. H. Beck

Energy of Grain Boundaries

Digest of "Grain Boundaries — Explanation of Microstructures in Terms of Energies", by D. McLean, *Metal Treatment and Drop Forging*, Vol. 23, January 1956, p. 3-10.

A grain boundary has two distinct features, the misorientation between the grains on each side of it and the structure of the boundary itself. The misorientation between grains affects the plastic properties of metals while the structure of a boundary is important in such processes as diffusion and age hardening. The evidence available on the structure of grain boundaries indicates that they consist of a misfit layer two or three atoms thick which resembles a thin layer of liquid. Four facts support this conclusion:

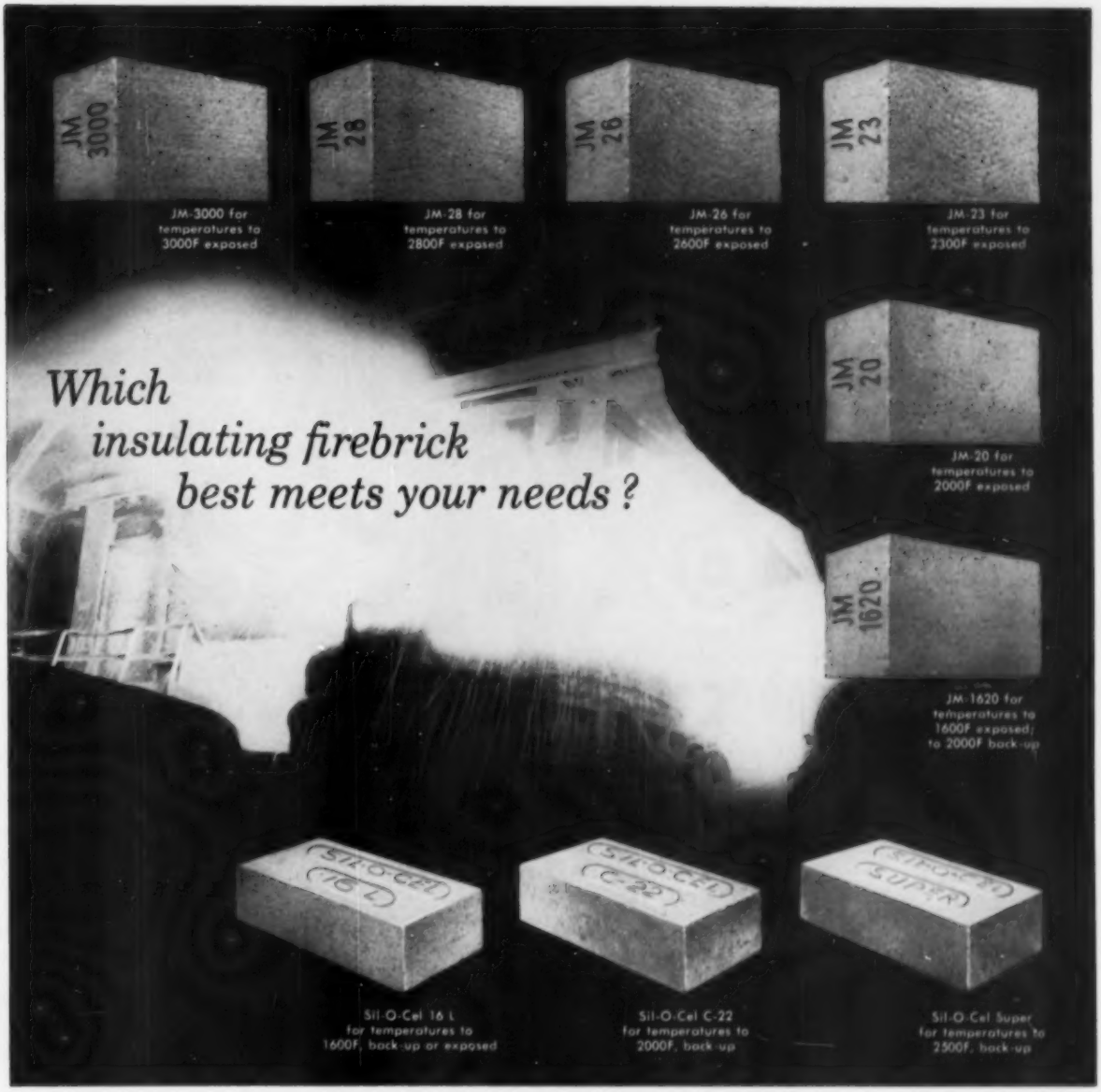
1. There must be a disorganized layer joining two different crystal lattices or two identical misoriented lattices and the layer must be thin to be consistent with the short range of atomic forces.

2. Such a structure is shown by the bubble model.

3. It is improbable that the misfit can be resolved into distinguishable dislocations as it can for boundaries where the misorientation is small, since the dislocations would have to be so close together that they would seriously distort each other.

4. The calculated energy of the postulated supercooled liquid layer is about the same as the measured energy.

Grain boundaries can be divided into two distinct classes which merge in the region where mis-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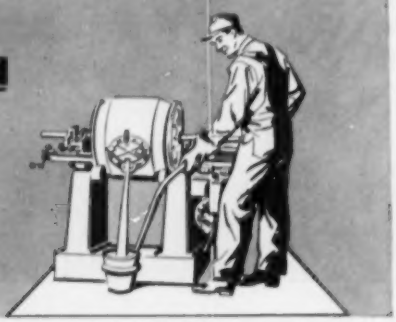

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Grain Boundaries . . .

orientation cannot be represented by a dislocation model. The low-angle boundary becomes less distinguishable from the neighboring grains as the misorientation is reduced and its physical properties vary correspondingly. On the other hand, the properties of ordinary grain boundaries are much less dependent on the angular difference between the neighboring grains. One of the physical properties of grain boundaries which at low angles is affected by misorientation is the grain-boundary energy. Since the boundary atoms do not lie in perfect lattice positions, they are not in positions of lowest energy. The extra grain-boundary free energy manifests itself as an interfacial tension equivalent to surface tension.

The methods of measuring grain-boundary energy require comparison with some other more accessible interface or surface and measurement of the energy of this interface. As a result, the methods of measurement are either relative or absolute. The relative methods all depend on the fact that surface or interfacial tensions in metals pull into equilibrium as they do at the junction of these soap films. If the section is normal to the junction line, then the ratios of the interfacial tensions to the sine of the opposite angles are equal. The only absolute method which has been used with success is one which requires comparison with the tension in the surface of the metal. Surface tension is determined from the equilibrium reached between the metal surface and the surface tension of a drop of liquid which does not wet the metal surface.

Grain shape is the result of the balance between the laws of surface tension equilibrium and the requirements of space filling. When all grain boundaries have the same tension, the grain boundaries meet along a line at an angle of 120°. When four grain boundaries meet at a point, the angle between the grain edges is that of a regular tetrahedron. Metal grains most frequently have 12 to 14 five-sided faces.

Upsetting the metastable equilibrium in a polycrystalline aggregate can result in grain growth. The mechanism of grain growth in a

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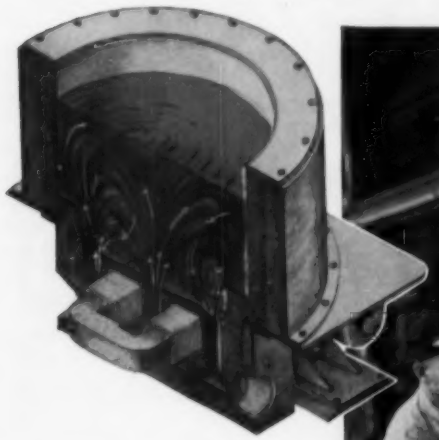

Cross section of AJAX-TAMA-WYATT twin coil induction furnace such as used at the Torrance Brass Foundry. Heat is produced within the molten metal in the secondary channels and conveyed throughout the melt by electromagnetic circulation, resulting in minimum metal losses and high uniformity of alloy. Temperature is automatically controlled.

(Photograph courtesy of Long Beach Press-Telegram, Long Beach, Calif.)

The furnace pictured above is melting aluminum bronze at the **Torrance Brass Foundry, Torrance, Cal.**, operating at a temperature of 2400 F, for the production of high strength centrifugal castings. This unit is rated 100 kw. Note also the clean, smokeless operation as shown in the unretouched photograph.

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Grain Boundaries . . .

system in which junction angles and lines are not in equilibrium is by rearrangement until the angles are pulled into equilibrium. This movement introduces curvature into the boundaries which tend to straighten and thus minimize their area. When neighboring junction points reach equilibrium, further change in the junction displaces the balance and migration occurs until a final balance is achieved. Grain growth, however, gradually slows down because the driving force for migration diminishes, the hindering effect of impurities increases as the curvature decreases and because locking mechanisms develop from structural requirements.

Consideration of the interaction between grain-boundary energies for two phases also provides a means for rationalizing the microstructures of two-phase alloys. Preferential grain-boundary precipitation is due to the fact that only about half as much new interfacial free energy is needed compared to precipitation inside a grain. It only occurs when diffusion is sufficiently rapid. When a second phase lies along grain boundaries in the parent phase, its distribution along these boundaries depends on the relation between the boundary energies.

The precipitate particles within a grain are often spherical because the boundary energy does not vary much with the orientation of the boundary itself. However, where the crystal lattices of the parent and precipitating phases have crystallographic planes with similar atomic spacing, a low-energy boundary can be formed. This can produce long thin particles, disk-shaped in three dimensions.

When the dihedral angle of a metal-liquid system is close to zero, the effect of temperature, composition or stress may become critical. The embrittlement of brass by mercury is probably an example of the effect of stress on the dihedral angle.

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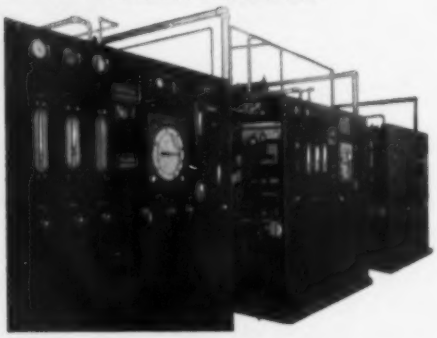

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CIRCO Metal Cleaning Equipment CUTS costs

SINCE 1923

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EQUIPMENT COMPANY

119 Central Avenue, Clark (Rahway), N. J.

Offices and warehouses in principal cities

CIRCO VAPOR DEGREASERS—large or small—automatic or manual operation

CIRCO METAL PARTS WASHERS—custom engineered to suit your production needs

CIRCO-SONIC DEGREASERS — newest development—cleaning by *ultrasonic* vibration

CIRCO-SOLV (Trichlorethylene) and PER-SOLV (Perchlorethylene) — high purity, low-cost solvents

FREE! Write for 32-page CIRCO Degreasing Manual

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WELDCO FABRICATED MONEL PICKLING EQUIPMENT

• Hairpin Hooks • Sheet Crates

• Steam Jets • Chain

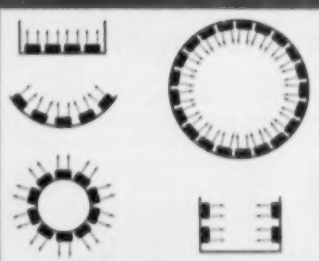
• Mechanical Bar, Tube and Coil Picklers

THE YOUNGSTOWN WELDING & ENGINEERING CO.

3721 OAKWOOD AVE. YOUNGSTOWN, OHIO

LIST NO. 94 ON INFO-COUPON PAGE 168

ULTRASONIC CLEANING



Typical Transducer Arrangements

SONOGEN®

Ultrasonic-Power Generators with hermetically-sealed barium-titanate Transducers — 40Kc/sec.

Transducer Radiating Areas of ¼ sq. ft to 10 sq. ft. — for use in solvents and detergents.

Eliminates hand operations — Reduces rejects in plating, finishing, assembly.

For washing, degreasing, removal of buffing compounds, radioactive contamination, soldering flux, plaster, carbon smut, etc.

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Specializing in Ultrasonics Since 1946

4 BROWN HOUSE RD. STAMFORD, CONNECTICUT

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MANHATTAN

Abrasive Wheels — Cut-off Wheels
Finishing Wheels—Diamond Wheels

Custom-made for your specific material removal problems

Foundry Snagging—Billet Surfacing—Centerless Grinding

Cutting and Surfacing concrete granite, and marble

"Moldiscs" for rotary sanders

Grinding and Finishing stainless steel welds

Bearing Race Grinding and Finishing

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Cutting-off—Wet or Dry Bars, Tubing, Structurals, etc. Foundry Cutting —standard and reinforced wheels

Grinding Carbide Tipped Tools

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Write to Abrasive Wheel Department

Raybestos-Manhattan, Inc.

MANHATTAN RUBBER DIVISION

92 TOWNSEND ST. • PASSAIC, N. J.

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RUST-LICK IN AQUEOUS SYSTEMS

Grade "B"

FERROUS METAL PROCESSING

Eliminates . . .

Rust
Fire Hazards
Toxicity
Dermatitis
Degreasing

Write for free sample and brochure
Specify Grade "B"

PRODUCTION SPECIALTIES, INC.

755 BOYLSTON STREET

BOSTON 16, MASS.

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A FULL LINE OF MIXERS
For Your Quenching Operations

Sturdy, dependable units for any size or shape, new or existing quench tanks; for single or multiple installations.

PORTABLE — easy to mount, and quickly adjustable to best, uniform agitation. Sizes 1/4 to 7½ HP.

FIXED—top-entering and side-entering units for pre-determined quench results. Sizes 1 to 25 HP.

FOR COMPLETE CATALOG WRITE TODAY

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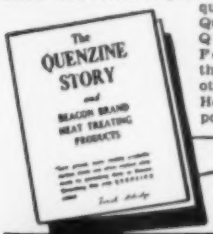
FREE

the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



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Upton

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the most advanced Salt Bath **Furnaces**

FOR . . . .

BATCH

CONVEYORIZED

ALUMINUM BRAZING

with continuing graphite electrodes

See us at

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Phone: Diamond 1-2520

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you can
DEPEND ON
Du-Lite
to meet your specifications

Du-Lite black oxide finishes for steel, stainless, copper, zinc or malleable iron provide a uniform, durable surface without altering the dimensions or physical characteristics of the metal. That's why they are often specified right on the blueprint.

And since the Du-Lite process is simple, flexible, and imposed at non-critical temperatures, you can depend on the results to meet your specifications—always.

Du-Lite black oxide finishes also meet govt. specs. MIL-F-13924, superseding 57-0-2C Type III Class A for steel and Class B for stainless (Type II Class B and C phosphates), and MIL-P-12011, superseding 51-70-1A para. 22.03 Class C for Copper and Copper Alloys.

Whatever your metal cleaning or finishing problem, consult—

Du-Lite
DU-LITE CHEMICAL CORP.
MIDDLETOWN, CONN.

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Your Stanwood Sales Engineer..
CAN HELP YOU WITH HEAT TREATING CONTAINER OR FIXTURE PROBLEMS!
There is a Stanwood Man near you for consultation without obligation when you have problems involving equipment for handling parts through heat treating, quenching, pickling, degreasing or similar processes. For a generation we have specialized in the design and construction of baskets, trays, fixtures, hangers, carburizing boxes, retorts and furnace parts. You can profit by our experience. Let us put you in touch with your Stanwood Man.
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CHICAGO 39, ILLINOIS
FABRICATED METAL PRODUCTS
CARBURIZING BOXES
BASKETS
FIXTURES
TRAYS
QUENCH TANKS
RETORTS

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BASKETS

for all industrial requirements

for de-greasing — pickling
anodizing — plating
materials handling
small-parts storage

of any size and shape —
any ductile metal

by

THE C. O.

JELLIFF MFG. CORP.

28 Pequot Road
Southport, Conn.

WIRE PRODUCTS Jelliff SINCE - 1880

LIST NO. 91 ON INFO-COUPON PAGE 168

WIRETEX Pit Furnace ASSEMBLY

cuts treating time 50%

lowers labor costs 66%

A well known foundry customer* substituted **WIRETEX** Inconel baskets and frames for cast iron pots and carriers for their pit type heat treating furnaces and discovered a way to save hundreds of dollars in labor, materials, maintenance and replacements. Best of all . . . production skyrocketed!

WIRETEX engineered baskets can do the same for you—it'll pay to investigate!

Specialists in processing carriers since 1932

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*Actual case history story, photos and WIRETEX catalog, free for asking. Write today!

Call Wiretex

- BASKETS
- MUFFLES
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- RETORTS
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to resist acids, heat, abrasion or exposure. Small, large — standard or custom made in every weave, metal and alloy.

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WHATEVER YOUR HEAT TREATING PROBLEM MAY BE

. . . there is a helpful Holden brochure that provides engineering data and assistance for you. Let us send the booklets that relate to your operations—without obligation, of course. Bulletin 200 covers Salt Baths; 201—Pot Furnaces; 203—Cleaning and Descaling; 204—Pressure Nitriding Process; 205—Industrial Furnaces and New Luminous Wall Firing; 206—Austempering and Martempering.

HOLDEN METALLURGICAL PRODUCTS GIVE YOU MORE FOR YOUR MONEY . . . REQUIRE LESS SUPERVISION . . . HAVE PROVEN PERFORMANCE AND PROVEN GUARANTEES . . .

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MANUFACTURING PLANTS

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CIRC-AIR HEAT TREATING FURNACES

for Every Heat Treating Process

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CONTROLLED ATMOSPHERES

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CIRC-AIR NICARB
(CARBONITRIDING)

Specially Engineered for Your Particular Needs

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GAS • OIL • ELECTRIC

INDUSTRIAL HEATING EQUIPMENT COMPANY

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SWIFT CASE 560 LIQUID CARBURIZER

FOR . . . A tougher, more durable case

. . . Fast, free washing

. . . Maximum versatility

Completely water soluble—free washing even after oil quenching—higher hardness with *maximum toughness* and surprising production economy!

Send today for technical data sheets

Swift INDUSTRIAL CHEMICAL CO.
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Impressor

for quick, on-the-spot hardness testing of non-ferrous metals and plastics

Simple to operate . . . gives an instant, dependable measure of hardness. Operates on principle of forcing a spring-loaded indenter into the surface with the amount of penetration registering on a dial indicator. Can be used in any position . . . tamperproof . . . compact . . . rugged, yet weighs only 12 oz. Thousands used by industry. Write today for complete details.

Barber-Colman Company

Dept. G, 1218 Rock St., Rockford, Illinois

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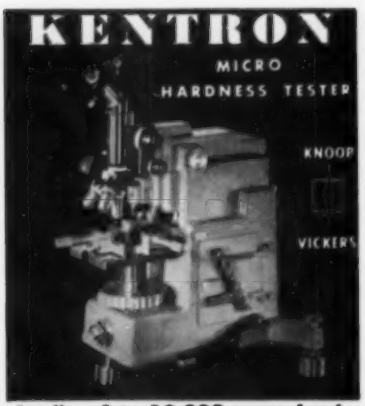
KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

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Kent Cliff Laboratories Div.

The Torsion Balance Company

CLIFTON **NEW JERSEY**

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More than two thousand satisfied users WILL TESTIFY YOU

SAVE 3 WAYS WITH A LUCIFER FURNACE

1—Save on First Cost

CHECK THESE PRICES

Furnace Size	2000°	2300°
6x 6x12"	$ 500.00	$ 600.00
9x 9x18"	750.00	850.00
12x12x24"	1000.00	1100.00
18x18x36"	1500.00	1600.00

Complete with 100% automatic electronic controls.

2—Save on Man Hours

Less operator attention needed—Lucifer controls are EXACT. They reach SPECIFIED heat rapidly and retain SPECIFIED temperature without variation. No special experience required when you use a Lucifer Furnace.

3—Save on Maintenance

Finest refractory materials are built into Lucifer Furnaces for better, more efficient heat retention. Elements are guaranteed, long lived, trouble free.

WRITE FOR FREE LITERATURE, specifications and price list of Lucifer Furnaces in wide range of sizes—top loading and side loading types. Engineering advice without obligation. Write, wire or phone today.

LUCIFER FURNACES, INC.

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Phone [illegible]-0411

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dyna-trol ELECTRIC FURNACES

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
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Automatic Controls Available on all Models

MODEL P2472-1

MODEL P-79

- Infinite zone temperature control.
- Zone temperature indication by Pyrometer Selector Switch.
- Automatic hold and cut-off instrument available.
- Patented element holders.
- Infinite variety of time-temperature curves obtainable.
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OVER 40 STANDARD MODELS • WRITE FOR LITERATURE

L&L MANUFACTURING CO.

INDUSTRIAL DIVISION

CHESTER 77, PA.

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Inspection Demagnetizing or Sorting PROBLEMS?

SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

MAGNETIC ANALYSIS SPECIAL EQUIPMENT

Electronic Equipment for non-destructive production inspection of both non-magnetic stainless and high temperature steel bars and tubing—seamless or welded—as well as non-ferrous bars and tubing. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed 200 ft. per minute.

Over 30 installations in mills and fabricating plants.

MAGNETIC ANALYSIS COMPARATORS AND METAL TESTERS

Electronic Instruments for production sorting both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

MAGNETIC ANALYSIS DEMAGNETIZERS

Electrical Equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETIC ANALYSIS MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

TRADE MARK

For Details Write:

MAGNETIC ANALYSIS CORP.

42-44 Twelfth St., Long Island City 1, N. Y.

"THE TEST TELLS"

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Ask the Man Who KNOWS Stainless Welding . . .

Call Mr. Electrode . . . His years of experience and leadership in providing the correct—

Stainless and Heat Resistant Arc Welding Electrodes
—place a trusted guarantee back of your welding operations.

Automatic Welding . . .
- All Analyses
- Coated, Straightened
- Cut • Coiled and Spooled

MAURATH, INC.
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Phone: MOntrose 2-6100

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Get these important
FIELD REPORTS
on Metalworking Lubrication with
MOLYKOTE® LUBRICANTS

. . . a "MUST" in every metalworking shop and design department

. . . hundreds of case histories from customer files . . . prepared especially for the metalworking industry . . . send for them today.

THE ALPHA MOLYKOTE CORPORATION
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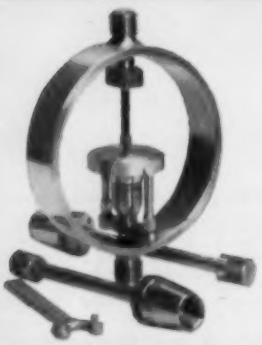

HOW OFTEN SHOULD TESTING EQUIPMENT BE CALIBRATED?

. . . *frequently*, to maintain true dependability. To achieve the ultimate in reliability, many manufacturers insist on periodic checking with Morehouse Proving Rings.

These precision instruments are sensitive to within .00001 inch . . . keep your equipment at "razor edge" accuracy. Their calibrating range is from 50 to 300,000 lbs. Certified by the National Bureau of Standards. Write for new, illustrated brochure.

Also investigate Morehouse Ring Dynamometers, Weighing and Calibrating Systems.

MOREHOUSE MACHINE COMPANY
"World Leader in Precision Calibration"
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A CABLE SPLICED IN 10 SECONDS!

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Complete Arc Welding Accessories
2070 E. 61st Place, Cleveland 3, Ohio
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GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF
Die Castings
SINCE 1922
Aluminum and Zinc

HOOVER

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio

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HARDNESS TESTING
SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

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90-35M Van Wyck Exp., Jamaica 35, N.Y.

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Patent Pending

Accurate tensile specimens machined from .002"-.125" ferrous & non ferrous sheet in *less than three minutes!*

***TENSILMARK* for rapid and accurate scribing of gauge marks on specimens.**

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HORSE PLAIN ROAD • NEW BRITAIN, CONN.

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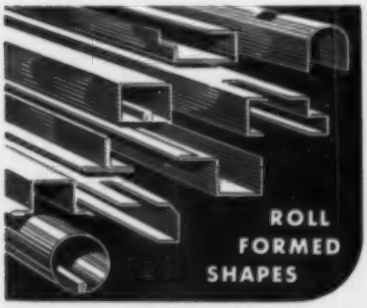

Reduce your assembly problems and costs. Our shapes continuously formed, with high degree of accuracy, from ferrous or non-ferrous metals. Write for Catalog No. 1053.

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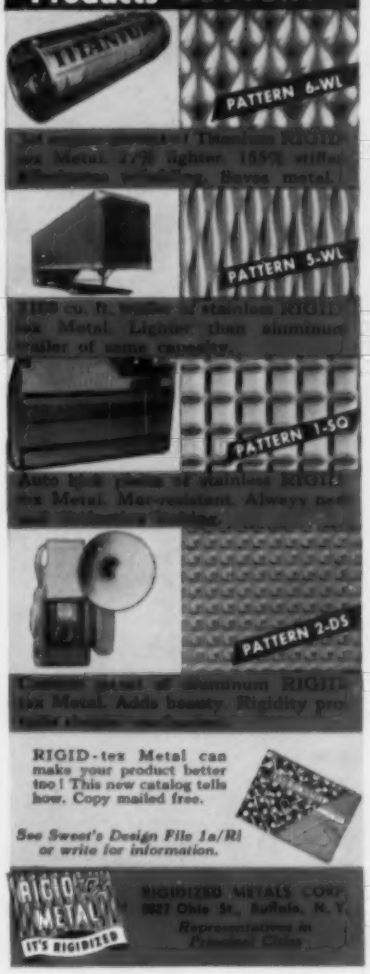
RIGID-tex METAL
Makes all these Products BETTER!



RIGID-tex Metal can make your product better too! This new catalog tells how. Copy mailed free.

See Sweet's Design File 1a/Ri or write for information.

RIGID METAL — IT'S RIGIDIZED

RIGIDIZED METALS CORP.
3827 Ohio St., Buffalo, N. Y.
Representatives in Principal Cities

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IN **BRINELL** AND **VICKERS** TESTS

SAVE TIME and TROUBLE

Eliminate the Tedious Microscopic Measurements of the Indentations.

Use Gries REFLEX Machines with Carl Zeiss Automatic Projection System

INVESTIGATE
Write for Bulletin No. A-14

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

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The New
"DERMITRON"
NON-DESTRUCTIVE THICKNESS TESTER

FAST
ACCURATE
PORTABLE
COMPACT
DIRECT READING

For Metals on Metals
Non-Conductors on Metals
Metals on Non-Conductors

You can have 100% inspection of production of nearly any possible coating on almost any base. The first and only non-destructive tester which gives fast, accurate, direct readings of such combinations as silver on brass, copper on zinc, metallizing on plastics, paint on metals—without the use of chemicals.

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New *Bondable*
Teflon® and Rulon®
in tape, film, other forms

Most people thought Teflon and Rulon could never be strongly bonded or cemented to other materials. No solvents affect them — no common chemicals attack them — they are extremely slippery and non-adhesive.

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*Dupont's tetrafluoroethylene resin

DIXON Corporation Est. 1876

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CORROSION RESISTANT

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Direct NEW YORK 'phone WI 7-9041

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MAGNESIUM

your comprehensive independent mill source of magnesium alloy
Tubes • Rods • Shapes • Bars
Hollow Extrusions • Plate • Sheet
• Pipe • Wire • Welded and
Riveted structures and assemblies

WHITELIGHT MAGNESIUM

WHITE METAL ROLLING
& STAMPING CORP.
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Sales Office
376 Lafayette St., New York 3, N. Y.

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EpCo

A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING
Special Feature —Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.

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The 1955 Supplement to the Metals Handbook

- 200 Large Pages
- 214 Tables
- 256 Charts
- 411 Illustrations

Order now a copy of the clothbound 1955 Supplement to increase the usefulness of your ASM Metals Handbook. The Supplement gives an authoritative survey of facts on these subjects:

Sheet Steel
Press Forming Dies
Gray Cast Iron
Stainless Steel
Aluminum Alloy Castings
Closed-Die Forgings
Helical Steel Springs
Surface Finish
Residual Stresses
Electroplated Coatings
Induction Hardening
Flame Hardening
Gas Carburizing
Control of Surface Carbon
Heat Treating of Tool Steel
Manual Arc Welding
Metal Cleaning Costs
Creep and Creep-Rupture Tests
Radiography of Metals
Macro-Etching of Iron & Steel

Each article gives a comprehensive coverage of its subject, with information limited to essential facts. This authoritative survey was prepared by 19 ASM technical committees comprising 179 outstanding engineers. For complete details of contents, see August 15, 1955, issue of Metal Progress, which contains the articles being offered in this clothbound edition. Price is $4.00 to ASM members, $6.00 to nonmembers.

American Society for Metals
Room 790, 7325 Euclid Ave.
Cleveland 3, Ohio

Please rush me the 1955 Supplement to the Metals Handbook.

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READERS' INFO-COUPON SERVICE, METAL PROGRESS
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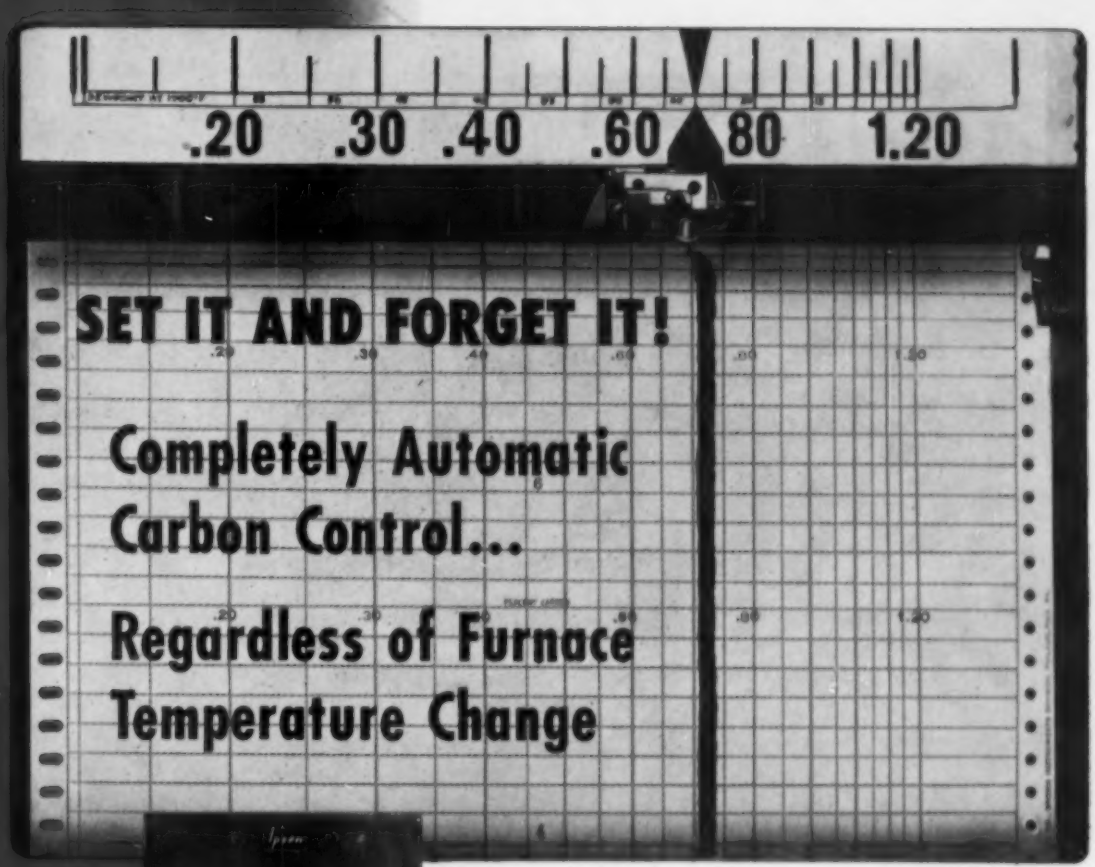


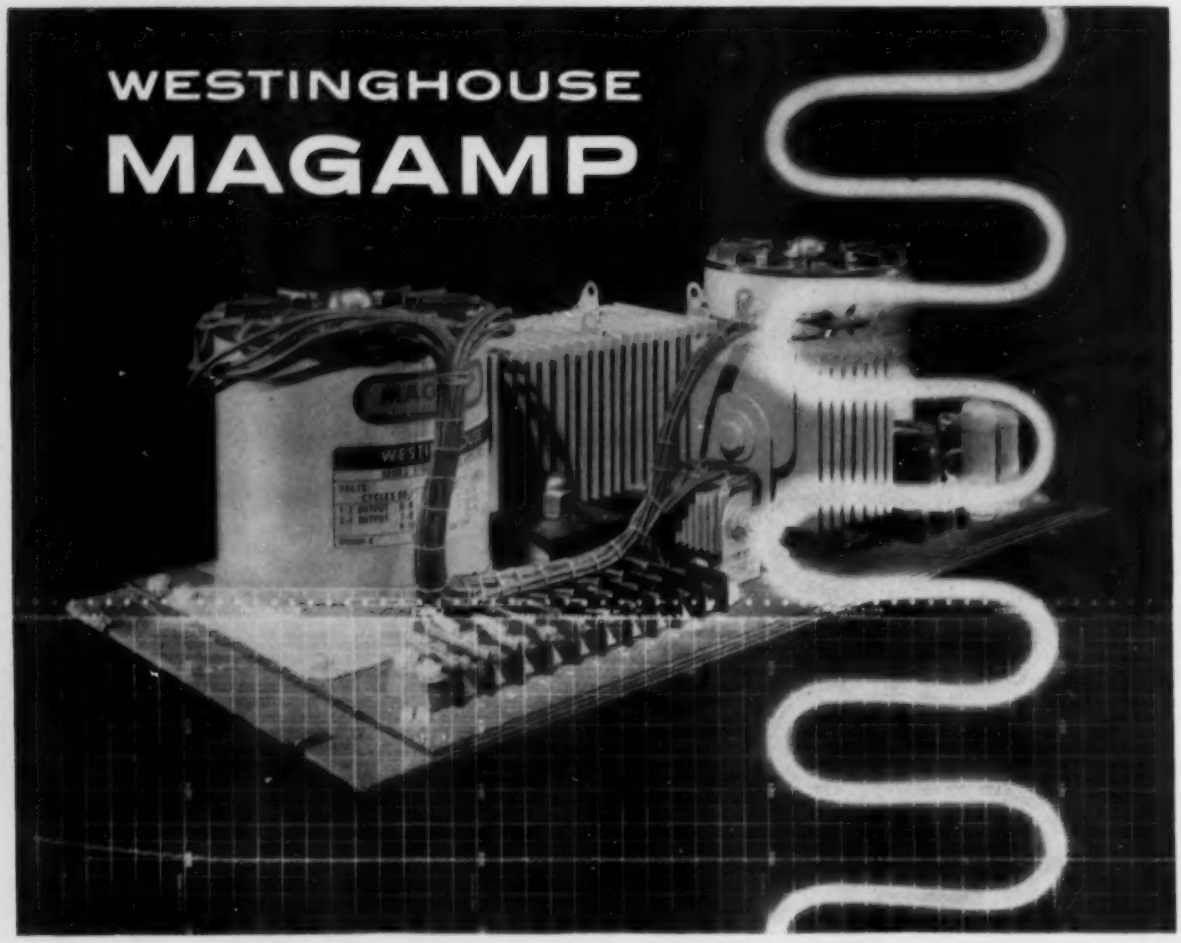
The CARBOTRONIK is a self-contained unit and can be placed at any distance from the furnace or generator being controlled. It records and indicates directly in percent carbon.

The Ipsen CARBOTRONIK carbon controller automatically coordinates furnace temperature and dew point to continuously provide any desired carbon potential from 0.20% to 1.25%. Enriching gas additions are made at the furnace and accuracy is ± 0.02% carbon over a range of 1400° F to 2000° F.

Dew points are measured every 5 seconds by a voltage type element. This sensing element is unaffected by ammonia or any other atmosphere gas and it does not require calibration. The operator merely sets the selector to desired carbon content and any furnace temperature changes are compensated for automatically.

IPSEN INDUSTRIES, INC.
717 South Main Street, Rockford, Illinois

AUTOMATIC Ipsen HEAT TREATING UNITS



Links temperature control with ten times longer life

With Westinghouse Magamp* magnetic amplifiers you can assure extraordinary predictable life for the critical job of amplifying temperature control signals; plus the fact that Magamp controls bring significant dollar savings.

Actually, these link units are rated for at least 20 years of stable, trouble-free service. They are unaffected by heat, dirt or corrosive atmospheres and have no moving parts to stick or jam. In standard panel assemblies, you can apply Magamps for control on industrial furnaces regardless of size.

In most cases, Magamp link units offer first cost savings of up to 50% over conventional controls. You'll see lower lifetime costs, too, since Magamp eliminates replacement and maintenance expense of conventional electronic controls.

Further facts, ratings, and application data for standard Magamp link units are yours in a free Facts Folder. Contact your local Westinghouse sales engineer, or write: Westinghouse Electric Corporation, 3 Gateway Center, P. O. Box 868, Pittsburgh 30, Pennsylvania.

*Trade-Mark

J-01006

WATCH WESTINGHOUSE!

*WHERE **BIG** THINGS ARE HAPPENING **TODAY!***

A NEW high finish and inherent beauty that comes through in the finished product makes certain grades of Sharon Stainless Steels practically indistinguishable from fine silver.

Think for a moment how this extra quality will enhance the appearance, utility and saleability of your product.

Which one is the

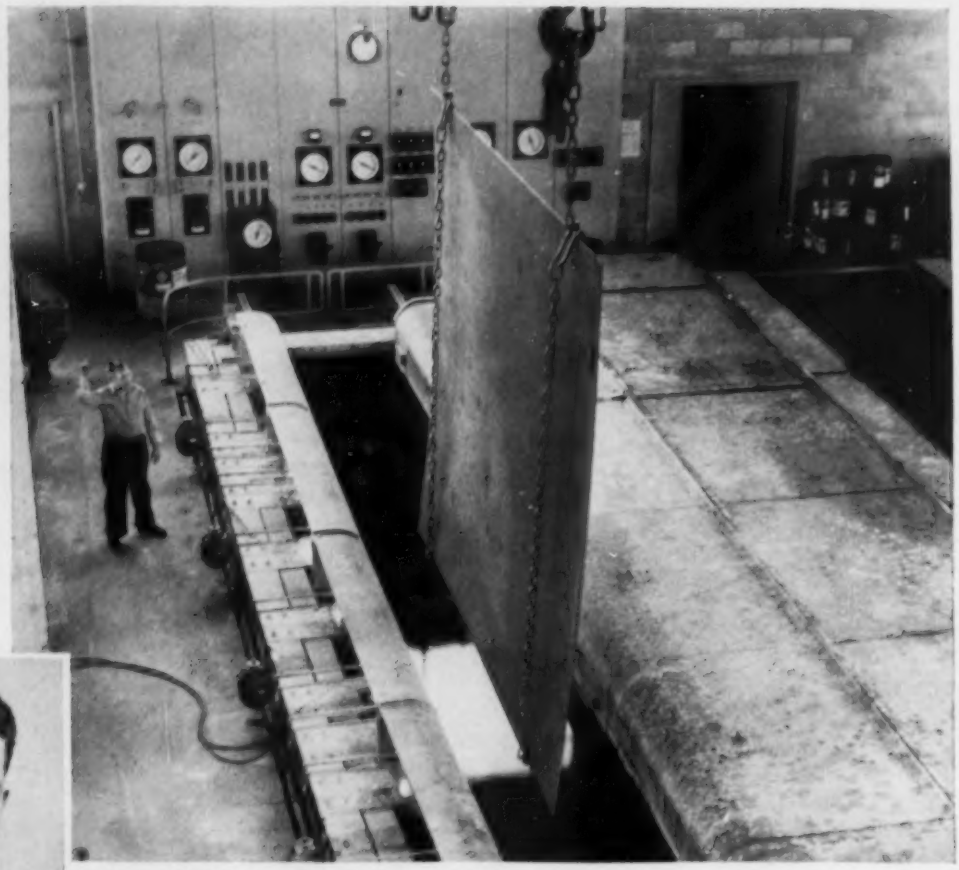
Stainless Steel?

Stainless Steel Tableware never dulls, or tarnishes...self-polishes with use.

SHARON Stainless Steel

SHARON STEEL CORPORATION SHARON, PA.

DISTRICT SALES OFFICES: Chicago, Cincinnati, Cleveland, Dayton, Detroit, Grand Rapids, Indianapolis, Los Angeles, Milwaukee, New York, Philadelphia, Rochester, San Francisco, Sharon, Seattle, Montreal, Que., Toronto, Ont.



FRANK HOLT, metal-treating specialist, gave the expert advice which helped Lukens to improve production and lower costs. He's one of the team of specialists that help Du Pont customers solve common and uncommon problems. These men have the practical experience and training to handle metal descaling problems. Why not call the specialist nearest your plant? Just phone or write the Du Pont office nearest you.

Du Pont District Offices: Baltimore, Boston, Charlotte, Chicago, Cincinnati, Cleveland, Detroit, Los Angeles, New York, Philadelphia, San Francisco.

How Lukens Steel cut cost of descaling stainless

On-the-job study led to use of carbon cover and many economies

Lukens Steel Company, Coatesville, Pa., has the world's largest sodium hydride descaling installation. The bath handles unit loads of from 12 to 15 tons of clad and stainless-steel plate, in sizes up to 450″ x 190″.

The Lukens installation has been operating since 1947. From the start, the clean, bright, smooth surfaces of the treated plate showed up as strong selling points for their stainless. The surface on this plate particularly pleased fabricators of equipment for the food and chemical industry. Lukens was getting quality descaling at reasonable cost, but Du Pont's technical service thought that this could be improved. An on-the-job study indicated that a charcoal cover would save money. Lukens took the advice of the Du Pont descaling specialist, and adopted the procedure. A much higher hydride content was obtained; sodium and ammonia consumption dropped 40%. The cover produced a more uniform bath temperature with lower heat losses, and consequent savings in power.

This assistance is typical of Du Pont service. Experienced men are available to help in installation and efficient operation. This service doesn't end when the Du Pont process or product goes into use. It's there—at all times—when you can use it or need it. E. I. du Pont de Nemours & Co. (Inc.), Electrochemicals Dept., Wilmington 98, Delaware.

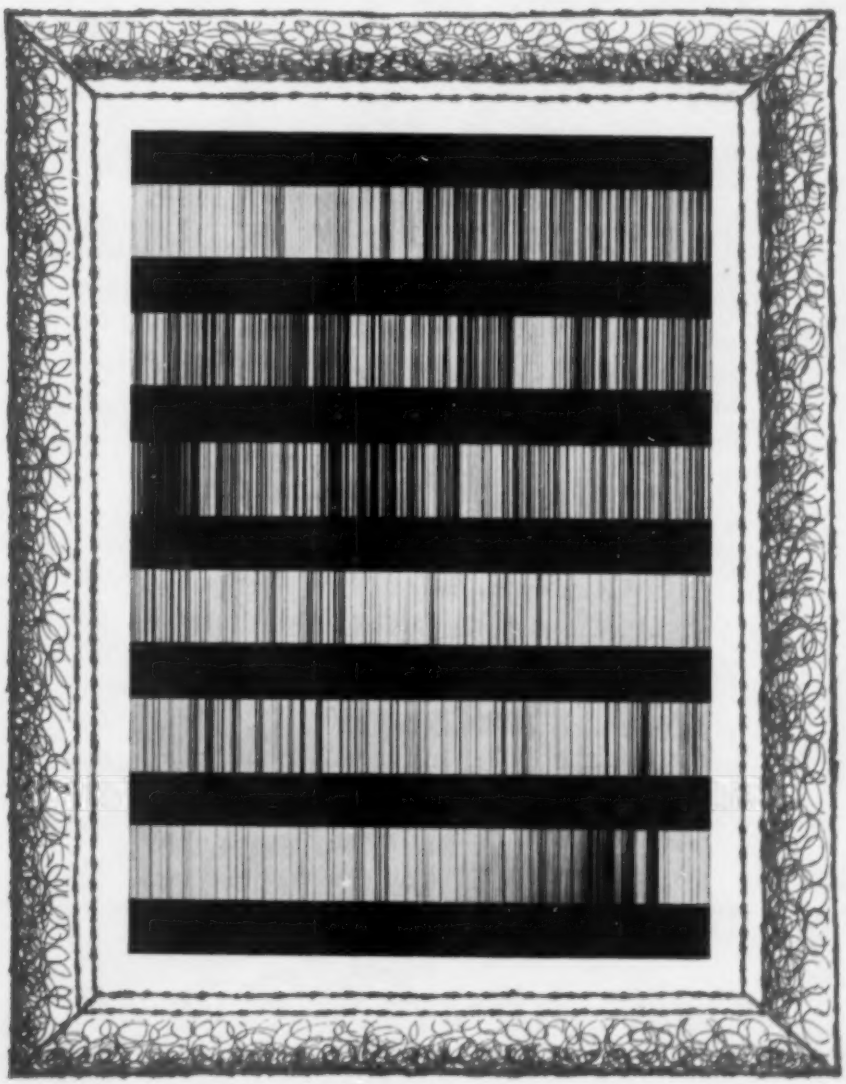
DU PONT

REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
..THROUGH CHEMISTRY

SODIUM HYDRIDE PROCESS FOR POSITIVE DESCALING

PORTRAIT OF A CHAMPION



Nichrome*, the famous alloy whose spectrogram you see here, is as truly a masterpiece as any Rembrandt or DaVinci hanging in the galleries—and for largely the same reason.

For the principal elements in Nichrome, *anyone* can combine. What gives Nichrome its unapproachable superiority over all other heat-resistance alloys, is the truly personal elements that go into its making—the all-important, highly specialized skills of the Driver-Harris technicians.

Step-by-step from melting through every processing operation, from furnace to finished spools of wire (some drawn as fine as .0005 dia.) exacting metallurgical controls and checks operate to assure the peerless and enduring qualitites of Nichrome. These quality controls represent 58 years of continuous alloy research that have established Nichrome as the time-tested standard by which all similar alloys are measured.

Yes, there is only one Nichrome, and it is made only by Driver-Harris.

And in recognition of its unique properties, the United States Patent Office in August, 1908, granted solely and exclusively to us the trade-mark NICHROME.

*T. M. Reg. U. S. Pat. Off.

Driver-Harris COMPANY

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Louisville, Los Angeles, San Francisco • In Canada: The B. GREENING WIRE COMPANY, Ltd., Hamilton, Ontario

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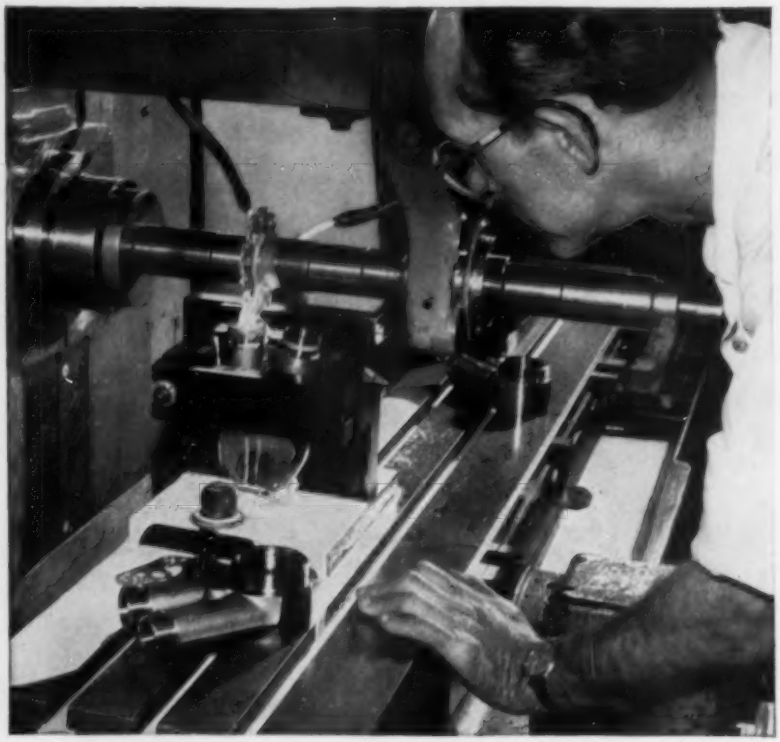
MALLORY·SHARON
reports on # TITANIUM



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This is another example of the rapid development of titanium —in which Mallory-Sharon has played a leading role. Call us for the full range of titanium and titanium alloy mill products, and for engineering assistance in fabrication and application.

"PHYSICAL METALLURGY AND HEAT TREATMENT OF TITANIUM ALLOYS"

This authoritative 60-page book published by Mallory-Sharon defines and clarifies titanium alloy heat treatment and recommended practices. Data is based on an investigation carried out under Navy contract at the Mallory-Sharon Research Laboratory. Price $1 each; order copies from Mallory-Sharon Titanium Corp., Dept. F-7, Niles, Ohio.

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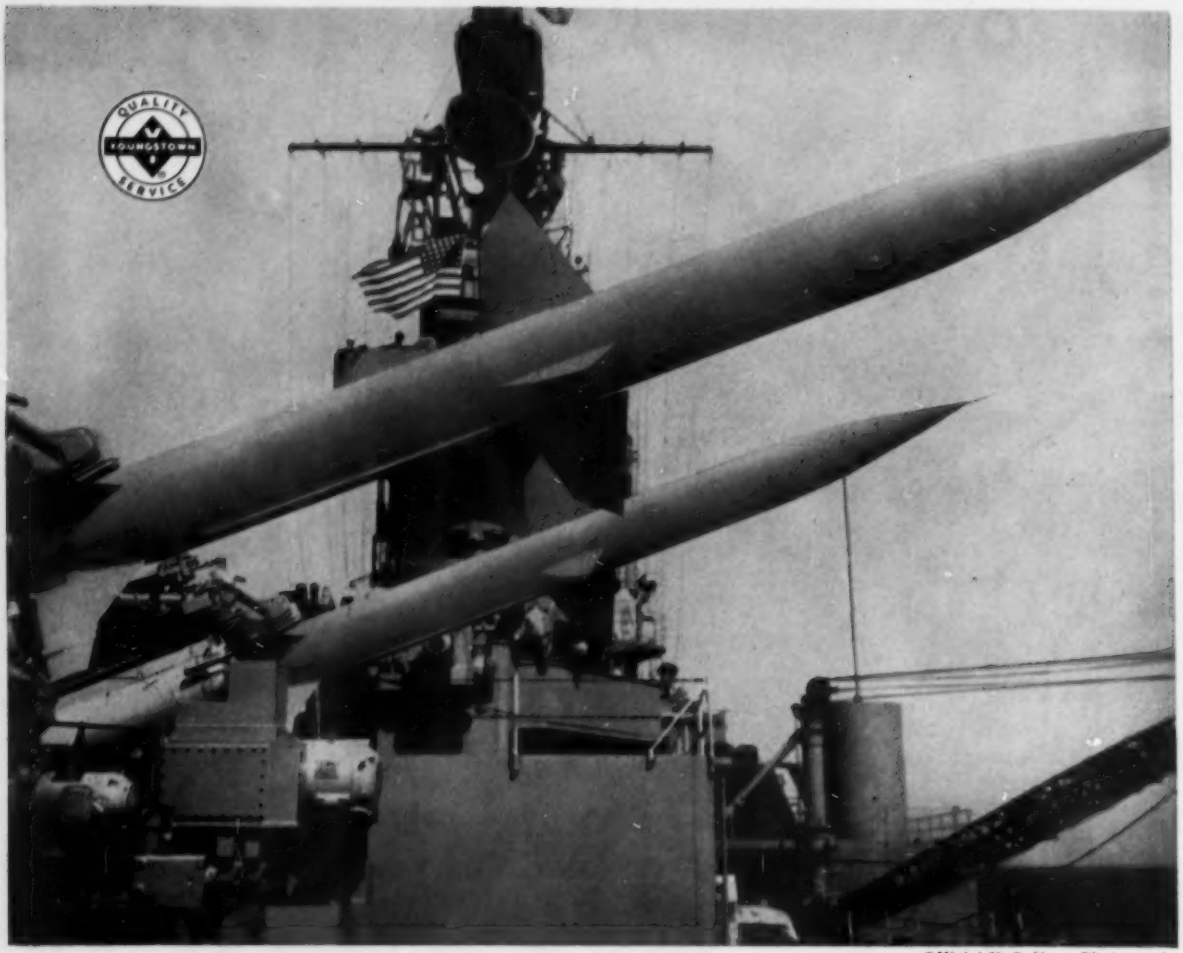

Official U. S. Navy Photograph

Supersonic tracker of enemy planes

Now guarding our coast, U. S. Navy's new guided missile has vital parts of Youngstown Alloy Sheets

Combining metallurgical skills of steelmaking with modern marvels of electronics, Terrier Guided Missiles are capable of destroying hostile targets at long range with great accuracy. The Youngstown Sheet and Tube Company is proud of participating in the production of high quality steel used in these new weapons for our naval forces.

The booster and sustaining mechanism of the Terrier are fabricated of Youngstown Aircraft Quality Alloy Steel Sheets **by the Hicks Corporation.**

Youngstown Alloy Steels are produced in a variety of forms and qualities to meet customers' specifications. Every ton is subject to a close quality control which insures uniform chemical composition and mechanical properties.

Whenever you have requirements for steel, consider Youngstown Carbon Alloy or Yoloy—sheets, bars, plates or pipe.

Youngstown

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Manufacturers of Carbon, Alloy and Yoloy Steel

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Subject at hand . . .

INDUCTION HEATING EQUIPMENT

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Your induction heating specs receive full attention here. These engineers are specialists in induction heating equipment. Some are mechanical men . . . others are electrical. Together, they can design the simplest or most complex induction heating equipment, low or high frequency.

Magnethermic's personnel know heat-treating, hot working and joining. They know forging and brazing. Induction heating is our only business.

Magnethermic is the company that answered the need of the aluminum industry back in the '40s for an extrusion billet heater. Now, Magnethermic's expanded organization applies its experience to a full range of induction heating equipment . . . low, dual or high frequency, backed up by complete manufacturing facilities.

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RF THROUGH 10,000 CYCLES

Caterpillar Tractor Co. Metallurgist T. H. Spencer inspects final drive pinion for D9 crawler tractor weighing 28 tons. Severe loading of this large pinion requires a steel with high case and core hardenability. Several years ago Caterpillar Tractor Co. found that simply by increasing the molybdenum content of AISI 8622 (to 0.30-0.40%), the desired properties were obtained at lower cost than was possible in any of the standard carburizing grades.

Caterpillar Tractor Co. improves case and core hardenability of carburizing steel by increasing molybdenum content

"Drive pinions in tractors must take very high torque loads," says T. H. Spencer, Metallurgist for Caterpillar Tractor Co. "AISI 8622 steel, which we had been using, couldn't give us the hard case and strong, tough core we needed in these heavy sections. Other standard carburizing steels with the requisite properties would have cost substantially more. We found, however, that we could achieve the desired surface and core properties by simply modifying AISI 8622 with a higher percentage of molybdenum. We have been using this composition for several years, and results have been excellent."

Caterpillar Tractor Co.'s experience shows how increasing molybdenum in a carburizing steel helped to solve a specific problem. Perhaps your product, too, can benefit by higher molybdenum content.

A technical article, "New Carburizing Steels for Critical Gearing", describes some recent investigations of higher-moly carburizing steels. For a reprint, write Climax Molybdenum Company, Dept. 5, 500 Fifth Avenue, New York 36, N. Y.

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Use the Moly Key to better carburizing steels

- High case hardness
- Wide choice of hardenability
- Easy to heat treat
- Low distortion
- Good machinability
- Good wear resistance

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OUR FINE MACHINING – is a *plus* factor!

Finishing operations on GLC electrodes, anodes and mold stock are performed with the utmost precision. A strict system of gaging and inspection is required at this stage.

The craftsmanlike spirit of our milling, machining and inspection personnel is a distinctive *plus factor* in the efficiency of GLC carbon and graphite products.

The high degree of integration between discoveries in our research laboratories, refinements in processing raw materials, and improved manufacturing techniques is further assurance of excellent product performance.

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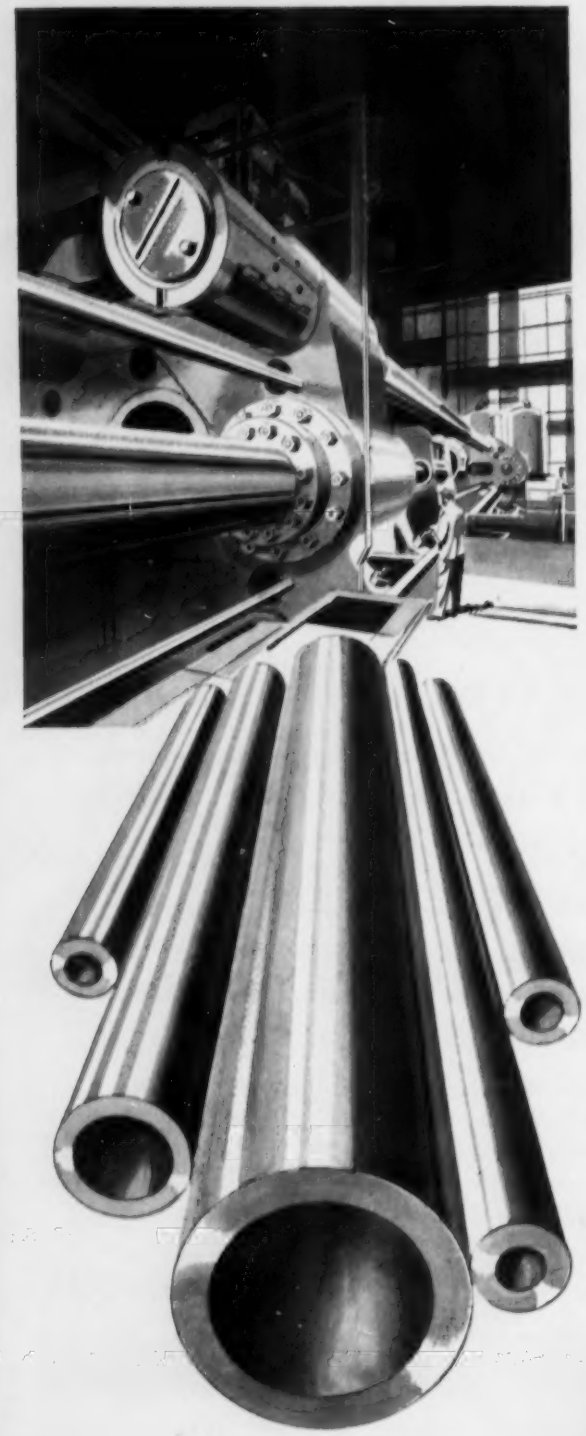
NOW! from the world's largest horizontal steel extrusion press...



SEAMLESS

HEAVY WALL PIPE

from any ferrous alloy

Now heavy wall pipe can be extruded from any ferrous alloy — in lengths up to 50 feet or more, with O.D.'s from 4″ to 22″, and with virtually no restriction on wall thickness.

The giant Curtiss-Wright horizontal extrusion press, now operating at the Metals Processing Division, *moves* the metal instead of *removing* it, for pipe of maximum length — and strength.

If your application calls for higher heat, corrosion and/or abrasion resistance — in pipe of highest tensile and yield strengths — Metals Processing Division is geared to fill the requirement. Complete facilities for handling any ferrous alloy, including the stainless series, as well as titanium and other reactive metals, are available to the chemical, petroleum, power and other key industries.

Take advantage of this new, aggressive facility for your pipe requirements. Write, wire or telephone for detailed information or engineering consultation today. Our field engineers are at your service.

METALS PROCESSING DIVISION

CURTISS-WRIGHT CW

CORPORATION • BUFFALO, NEW YORK

Crankshaft Machine Company uses La Salle's

NEW fatigue-proof STEEL BARS

to replace heat-treated alloy

- **140-150,000 PSI TENSILE**
- **MACHINES 50-100% FASTER**

FATIGUE-PROOF is specified in this automated turning machine manufactured by Crankshaft Machine Company, Jackson, Michigan.

This $60,000 machine uses FATIGUE-PROOF for a vital part. The rack that actuates the loading mechanism formerly was heat-treated alloy and is now FATIGUE-PROOF.

This is an automatic crankshaft turning machine that operates in automotive production lines. It must run dependably. The engine line can't wait for machine repairs.

The rack itself is intricate and machining it was a problem. FATIGUE-PROOF solved that, and it did so at no risk to the machine!

If you are producing parts requiring tensile strengths in the 140,000 to 150,000 p.s.i. range . . if you are interested in a steel bar that has this strength without heat treating . . if you want to trim production costs with a bar that machines faster (25% faster than annealed alloys, 50% to 100% faster than heat-treated alloys) . . if you want to eliminate the cost and inconvenience of heat treating, we invite you to send us a blueprint or detailed description of your application or, better yet, pick up your telephone and call your nearest La Salle Sales Engineer.

TEST FATIGUE-PROOF! If it appears that FATIGUE-PROOF can help improve the quality of your product or cut your production costs, your La Salle Sales Engineer will be glad to furnish you with a sample bar for testing in your own plant.

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Ask for your copy of this 20-page booklet which gives detailed information on the remarkable new FATIGUE-PROOF . . 29 pictures, tables, charts.

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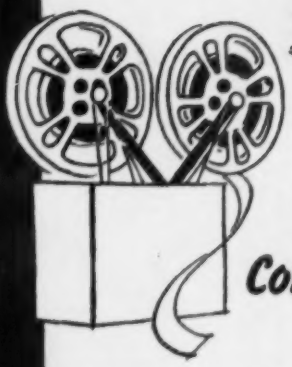


SEE! HEAR! how "Zinc Controls Corrosion"

Corrosion turns many thousands of tons of useful steel to scrap every single year. How this destructive action of the elements on steel can be delayed, minimized and controlled – thus avoiding mounting replacement and maintenance costs – is the subject of a new 16 mm. color and sound movie just released by the *American Zinc Institute*. In its 35 minutes of running time, "Zinc Controls Corrosion" presents a colorful demonstration of the general mechanism of corrosion as well as how zinc controls it.

The film uses the techniques of animation to show that, fundamentally, corrosion is the result of electrochemical action between dissimilar metals or different areas of the same metal. It explains how a galvanic cell is set up between dissimilar areas, or metals, causing the destruction of one of them and the protection of the other. While zinc has a high degree of corrosion resistance, and forms an effective and durable barrier between the steel and the elements, the film graphically illustrates that it is the sacrificial property of zinc in the presence of iron which is the key to the excellent protection which it affords vulnerable iron and steel products. Since the type of structure or product into which the steel is to go, and the kind of corrosive environment encountered, dictates the method of using zinc as a protective metal, the film also shows how steel is coated with zinc by means of galvanizing, electrogalvanizing, spraying, painting, metallizing, sherardizing, and how it is protected cathodically by zinc anodes.

Last, but not least, "Zinc Controls Corrosion" provides a fascinating insight relative to the many reasons why (a) nearly one-half of all the zinc consumed annually in the U.S. is used for the protection of iron and steel products and (b) that no program aimed at corrosion control can be fully effective without considering zinc – the protective metal.

ST. JOSEPH LEAD CO., 250 Park Ave., New York 17

above: *Exit section of continuous galvanizing line. The sheet steel emerges from zinc melting pot.*

right: *This scene from the film shows the galvanizing of hot water tanks in a bath of molten zinc.*

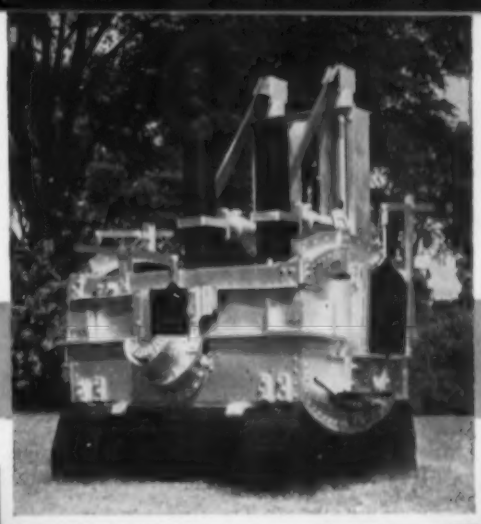
How to book "ZINC CONTROLS CORROSION"

The film is available for showing – at no charge – before agricultural, industrial, technical and educational groups. Prints can be borrowed from the *American Zinc Institute, Inc.*, 60 East 42nd St., New York 17, N. Y. Booking forms can be had on request.

HIGH GRADE
INTERMEDIATE
PRIME WESTERN

ST. JOE *electrothermic* ZINC

INTRODUCED TO THIS COUNTRY in 1906 by the Halcomb Steel Company, the original American steelmaking furnace is now enshrined in a park on the grounds of Crucible Steel Company's Sanderson-Halcomb Works, Syracuse, N. Y. Installed and operated under the personal supervision of its inventor, the celebrated French scientist, Paul Louis Heroult, it was a three-ton, single-phase unit and the prototype of the modern Heroult electric furnace.



From France fifty years ago, came this

Faster, Cheaper Method of making High Quality Steels

The little Heroult shown above was the first electric melting furnace ever used in this country. Imported from France in 1906, it signalled the beginning of a new era of American steelmaking.

From the very beginning, the Heroult has been accepted as the most economical and best method of producing high quality special purpose steels; and today under certain conditions, large electric furnaces are competitive with open hearths.

Modern Heroult electric furnaces are available in sizes ranging in holding capacity from 6000 lbs. up to and in excess of 400,000 lbs. Both gantry and swing-type roof-removing mechanisms are available. Door-charging furnaces and furnaces of special design, including units equipped with austenitic steel bottoms to permit induction stirring, can also be supplied.

We welcome an opportunity to help you select and install the Heroult best suited to your requirements. Please remember, however, that because the Heroult is a precision-engineered unit made to your particular requirements, it is advisable to anticipate your future needs as far in advance as possible. *The Heroult we make and install for you will be the finest electric furnace that money can buy!*

ONE OF TWO 24'6" inside shell diameter Heroult electric melting furnaces installed in the ultra-modern mill of McLouth Steel Corporation in Detroit. These, the largest melting furnaces in the world, with transformer capacities in excess of 33,000 KVA, are capable of producing heats of more than 400,000 lbs. Featuring electro-mechanical controls throughout with swing-type roofs, they are equipped with the finest mechanisms and electrical apparatus available.

Heroult
ELECTRIC MELTING FURNACES

USS

AMERICAN BRIDGE DIVISION

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UNITED STATES STEEL

Carpenter ... pioneering in improved Tool, Alloy and Stainless Steels through continuing research

TEMPERATURE 110° F.
Permanent magnet assembly for watthour meter employing a magnetic shunt of Carpenter Temperature Compensator "30."
TEMPERATURE -15° F.

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This alloy, Carpenter Temperature Compensator "30", is produced by specialists under strict quality controls. It is another example of how Carpenter's pioneering role in producing *specialty* steels to meet *special* applications works for you in your effort to build better products at a reasonable cost.

And Temperature Compensator "30" is but one of many Carpenter specialties. Other "extremely sensitive" alloys in this line respond to very weak electrical currents . . . permitting you to design smaller, lighter weight units. Still another Carpenter High Nickel Alloy assures precision product performance with practically no size change through temperature ranges up to 400°F.

Take this step for product improvement, now: Write on your company letterhead for detailed information on Carpenter Temperature Compensator, Low Expansion, High Permeability and Glass Sealing Alloys in such forms as strip, wire, bars, tubing and forging billets.

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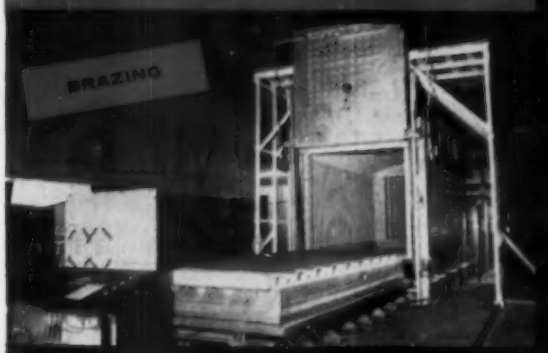
high nickel alloys

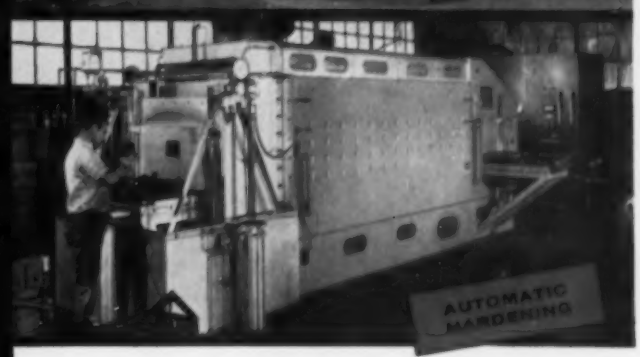
The Carpenter Steel Co., 133 W. Bern St., Reading, Pa.

Export Department: The Carpenter Steel Company, Port Washington, N. Y.—"CARSTEELCO"

there's a complete line of Pacific*-built furnaces

...ONE FOR YOUR *EVERY* HEAT TREATING NEED!





Whether it's *versatility* you need—a single furnace that can handle any number of different heat treating jobs efficiently —or a *specialized* piece of equipment to do a single job to super-critical tolerances—Pacific's complete line gives you *exactly* the right one for your job!

The installations shown here are just a few of Pacific's "standard" furnace designs. In addition, modifications or completely custom designed furnaces can be built to your own specifications. A Pacific field engineer will be glad to discuss your heat treating problems or requirements—write today!

Pacific INDUSTRIAL HEAT TREATING EQUIPMENT

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(type of work)

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Company

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THIS COMPLETE CATALOG ON UNITRON MICROSCOPES IS YOURS FOR THE ASKING

This colorful, illustrated catalog gives complete specifications on all of the instruments briefly described on this page, as well as others which we know will interest you. Send coupon below for your free copy.

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Please send us your complete catalog on UNITRON Microscopes.

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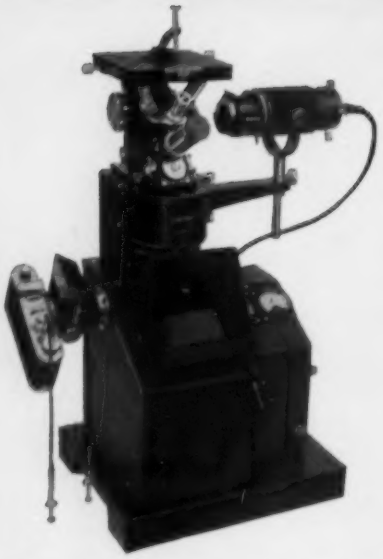

UNITRON METALLOGRAPH and UNIVERSAL CAMERA Microscope, New Model U-11

- For visual observation, measurement, and photography of both opaque and transparent specimens.
- Bright field, dark field, and polarized illumination.
- Revolving nosepiece with 5 objective lenses, 4 photographic eyepieces, 2 visual eyepieces. Coated optics. Magnification range: 25-2000X.
- Compact and entirely self-contained with built-in 3¼" x 4¼" camera, high-intensity illuminator, variable transformer.
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COMPLETE UNIT only fob Boston **$1145.**

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UNITRON Model MMU pioneers several new features available for the first time and, in addition, includes features found only in instruments selling for well over twice our unusually low price. For metals and other opaque specimens under both ordinary and polarized light. This model far surpasses the usual metallurgical microscope in versatility and makes an ideal all-purpose laboratory microscope. Its features include:

- transformer built into microscope base.
- vertical illuminator with iris diaphragm and filters.
- illuminator mounts on stage for oblique lighting.
- illuminator mounts substage for transparent specimens.
- coated optics.
- coarse and fine focusing.
- focusable stage.
- calibrated drawtube.
- polarizing apparatus and 5 filters.
- revolving nosepiece with objectives 5X, 10X, 40X, 100X, oil.
- eyepieces: P5X, P10X, K15X.

COMPLETE, only **$287.**

UNITRON STUDENT MODEL MMA

UNITRON Model MMA is a complete and versatile metallurgical microscope priced at about the usual cost of an accessory vertical illuminator needed to adapt an ordinary microscope for work with opaque specimens. Model MMA offers many of the novel features of the larger Model MMU insofar as these features are not connected with the higher magnifications obtainable with an oil-immersion lens. Its low cost makes the MMA ideal for student use and routine laboratory investigations. Its features include:

- transformer built into microscope base.
- vertical illuminator with iris diaphragm.
- illuminator mounts on stage for oblique lighting.
- illuminator mounts substage for transparent specimens.
- coated optics.
- single focusing control
- substage 5-hole disk diaphragm.
- frosted filter
- revolving nosepiece with objectives 5X, 10X, 40X.
- eyepieces: H8X, P8X, K15X.

COMPLETE only **$149.**

UNITRON Model MEC

is of the inverted type and designed for visual observation of metals, ores, minerals, etc. It includes many of the features of the Model U-11 Metallograph which are connected with visual observation of opaque specimens. 25-1500X.

- transformer built into microscope base.
- vertical illuminator with iris diaphragm.
- coarse and fine focusing.
- filters: polaroid, frosted, blue, green, yellow.
- large mechanical stage with graduated circular rotatable stage plate.
- calibrated polarizing apparatus.
- coated optics
- revolving nosepiece with objectives 5X, 10X, 40X, 100X oil.
- eyepieces: P8X, Micrometer 10X, K15X.

COMPLETE only fob Boston **$319.**

Binocular Model, only $493.

United Scientific Co.
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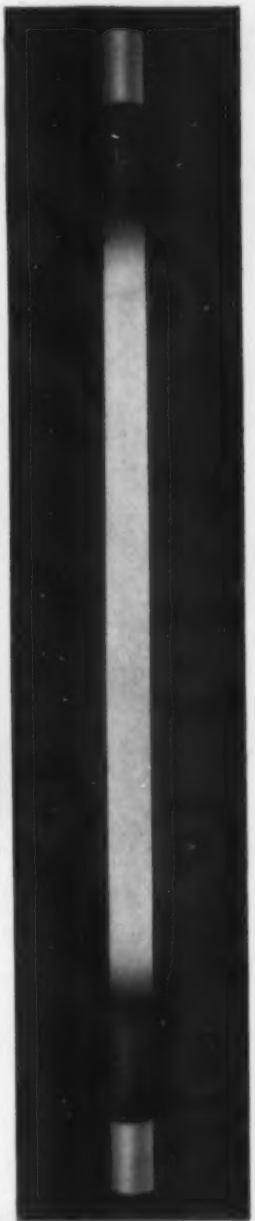
GLOBAR® *Heating Elements in this* DIETERT *laboratory furnace help gasoline company* SPEED SULFUR ANALYSIS



• This Sulfur Determinator installation in the laboratory of a leading gasoline company cuts sulfur analysis time from six hours to twenty minutes. "Varitemp" Combustion Furnace was designed and built by Harry W. Dietert Co., Detroit, Mich. — equipped with GLOBAR® Heating Elements.

ACCURACY IS ESSENTIAL in all phases of design, construction and operation of high temperature laboratory combustion furnaces. GLOBAR® Silicon Carbide Heating Elements — selected by Dietert and other leading electric furnace makers — provide uniform heat in a wide range, permit precise temperature control, and give long, dependable service.

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FREE CATALOG...gives detailed physical and electrical characteristics of GLOBAR® Silicon Carbide Heating Elements...mounting and control recommendations. Write for Bulletin "H".

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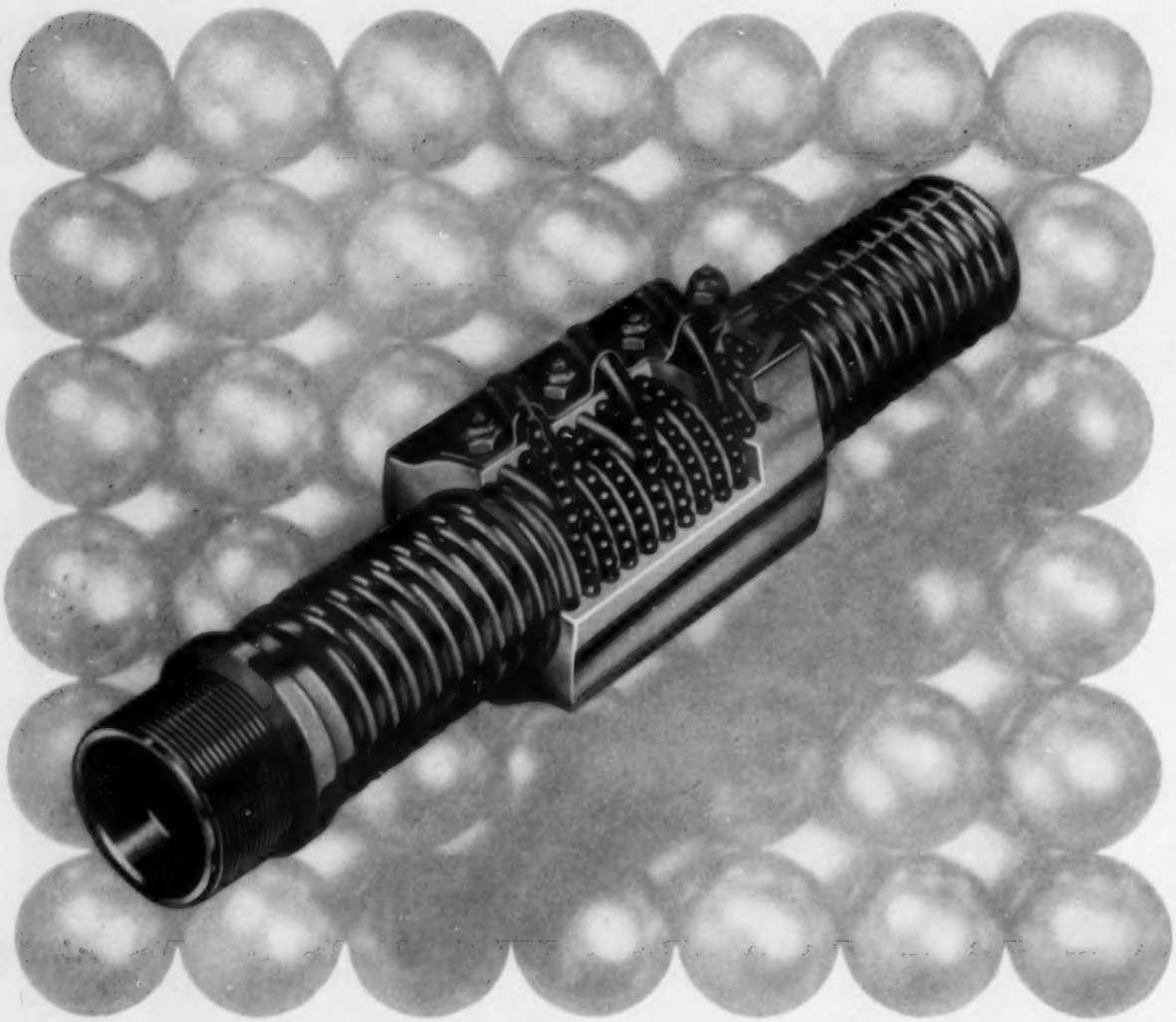

how Vacuum Metals' FERROVAC boosts ball bearing screw life up to 400%...

Ball bearing screw assemblies, first used in automobile steering mechanisms, are now found in such critical applications as the actuation of landing gear and control surfaces of aircraft and guided missiles. And it was in tough jobs like these that the assemblies failed in fatigue. Then a leading manufacturer tried vacuum-melted FERROVAC® for the balls – and service life rose as much as 400% over the original life. Here's why...

Vacuum melting improves fatigue properties – It literally sucks gaseous impurities – focal points for fatigue failure – from the molten metal. Vacuum-melted metals are cleaner, purer, tougher. And cleanliness means an added bonus in fewer rejects.

Only Vacuum Metals gives you one-source service – Vacuum Metal's own large organization, and its affiliation with National Research Corporation and Crucible Steel Company of America, means a fully integrated service from melting and casting through mill rolling and nationwide distribution of finished mill products. And you can get not only small experimental lots, but now, thanks to our new 2500 lb. induction furnace – the nation's largest – you can also get large-scale continuous production quantities of vacuum-melted metals. If you have an application which these unique metals may improve, please write giving full details. *Vacuum Metals Corporation, P. O. Box 977, Syracuse 1, New York.*

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VACUUM METALS CORPORATION

Jointly owned by Crucible Steel Company of America and National Research Corporation

Facilities of...
COMMERCIAL HEAT TREATERS
can cut YOUR costs

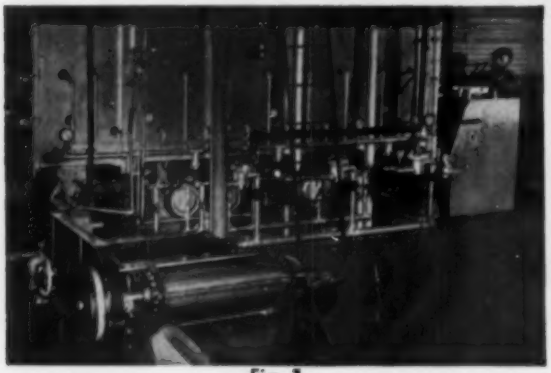

Fig. 1

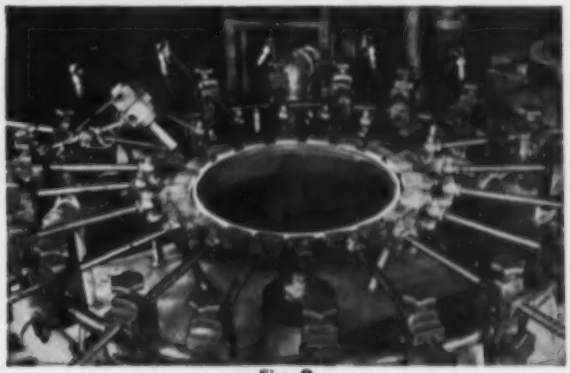

Fig. 2

An MTI commercial heat treater is located near you and is ready to serve your needs by performing "Custom-tailored" heat treating operations.

Because all members of the MTI are specialists with complete service facilities centralized in one plant, they are equipped to offer you a variety of heat treating processes—atmosphere hardening, carburizing, nitriding, annealing, cyaniding, etc.

For example, Fig. 1 shows an installation of a shaker hearth furnace with a continuous automatic quenching tank and a conveyor to a washing machine.

Fig. 2 illustrates a gas flame hardening unit featuring accurate temperature control and using two semi-circular gas manifolds mounted on movable carriages with 20 or more burner heads.

A further example of versatile and dependable equipment found in a commercial heat treating plant is seen in Fig. 3. The specially designed furnace conveyor belt carries over 35 lbs. per sq. ft. in normal service and sometimes as much as 5000 lbs. are loaded on it with pieces ranging from ½ lb. to 100 lbs. and temperatures up to 1650°.

Possessing such equipment together with many other specialized facilities and employing the trained personnel with technical knowledge and experience is the business of the commercial heat treater. Teamwork between you and the commercial heat treater can cut your costs.

Fig. 3

WRITE FOR *the booklet called:*

"STRATEGIC USE of OUTSIDE HEAT TREATING FACILITIES CAN CUT COSTS."

Consult any of these HEAT TREATING SPECIALISTS

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Cleveland 14, Ohio

Metallurgical, Inc.
Minneapolis 14, Minnesota

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Metlab Company
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Metro Heat Treat Co.
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New England Metallurgical Corp.
South Boston 27, Massachusetts

Paulo Products Company
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Pittsburgh Commercial Heat Treating Co.
Pittsburgh 1, Pennsylvania

The Queen City Steel Treating Co.
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Stanley P. Rockwell Company
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C. U. Scott & Son, Inc.
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Standard Steel Treating Co.
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Wisten Heat Treating Company
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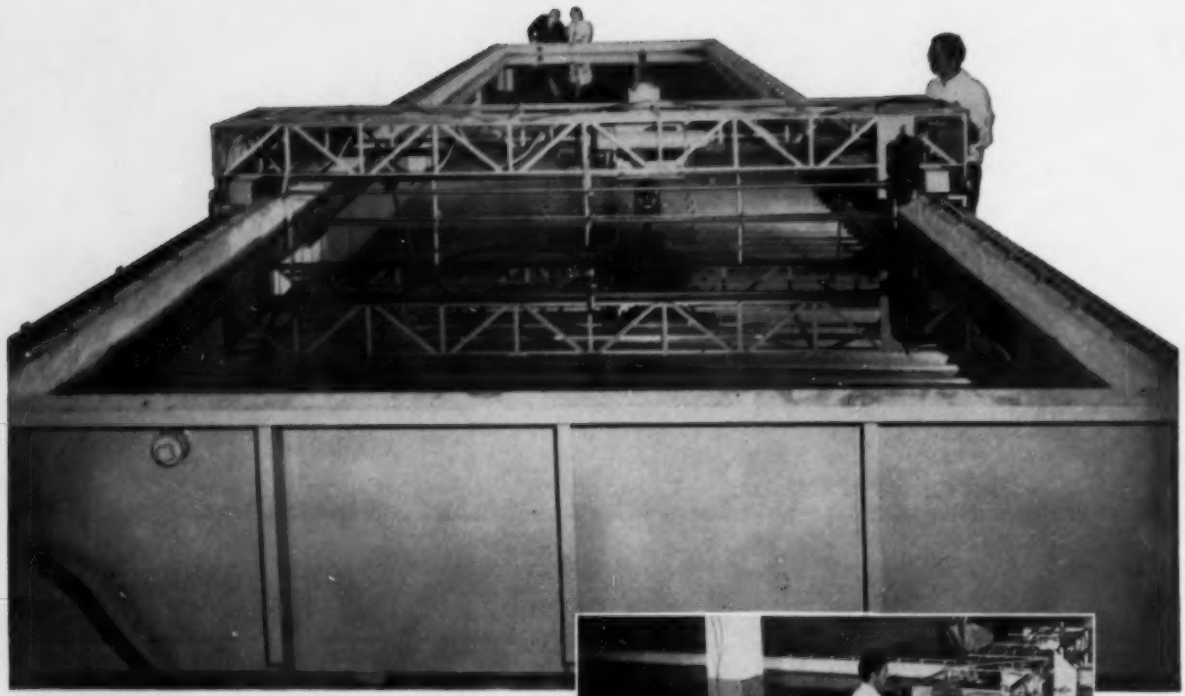
This advertisement sponsored by these Companies which are members of the Metal Treating Institute.



PRECISE QUALITY CONTROL Heart of the Curtiss-Wright System is a precision remote control manipulator mounted on the tank scanner assembly. It carries an underwater "search crystal" back and forth over the entire plate of aluminum, discharging vibrations of several million cycles a second which penetrate the metal. A cross sectional view of the material being inspected is presented by the "B" scan unit of the console.

LOWER COSTS FOR QUALITY The operating console provides complete control of scanner speed and sequences. Servo controlled mechanism provides four different scanning motions.

Photos courtesy Kaiser Aluminum & Chemical Corp., Trentwood, Wash. rolling mill

Curtiss-Wright

ULTRASONIC IMMERSCOPE

GUARDS QUALITY FOR KAISER ALUMINUM

Rolled aluminum has to meet rigid quality specifications—a problem made to order for Curtiss-Wright Ultrasonic Test Equipment. This ultra-modern system uses high frequency vibrations to provide more accurate inspections at lower costs, whether for aluminum, forgings, welded tubing, rolled plate, extrusions or other metal products.

Any flaw is immediately translated into a visible reading on the cathode ray tube of the Curtiss-Wright Immerscope. A built-in alarm system automatically marks the location of any flaw and at the same time provides visual indication of its size and location. By speeding inspection and reducing costs, Curtiss-Wright ultrasonics can give *your* production important quality control advantages. *For complete details write Industrial and Scientific Products Division, Curtiss-Wright Corporation, Caldwell, N. J.*

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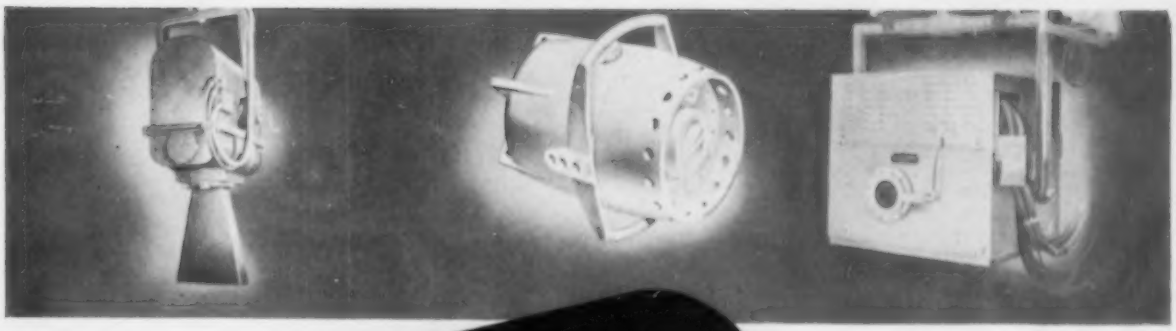
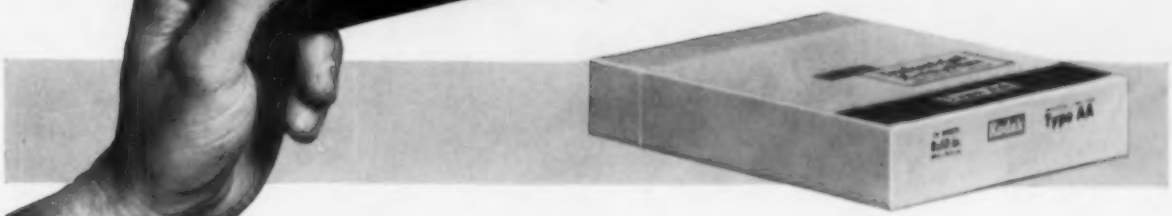


New Kodak X-ray Film

for

shorter exposures and quicker examinations

Kodak Industrial X-ray Film, Type AA



Read what the new Kodak Industrial X-ray Film, Type AA, will do for you.

- Reduces exposure time—speeds up routine examinations.
- Provides increased radiographic sensitivity through higher densities with established exposure and processing technics.
- Gives greater subject contrast, more detail and easier readability when established exposure times are used with reduced kilovoltage.
- Shortens processing cycle with existing exposure technics.
- Reduces the possibility of pressure desensitization under shop conditions of use.

Here is a brand-new x-ray film that gives you greatly increased film speeds. It is a film that retains the fine sensitivity characteristics which have made Kodak Type A the most widely used x-ray film in industry. Then in addition it gives speeds up to more than double those of Type A.

This means that you can cut down exposure time, handle routine examinations more quickly.

Your x-ray dealer and the Kodak Technical Representative are ready to tell you all about this new film. Get in touch with them. See what it will mean to you.

EASTMAN KODAK COMPANY
X-ray Division
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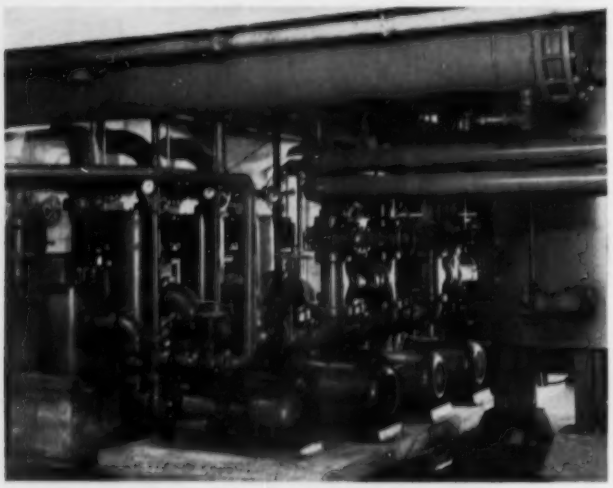
Kodak
TRADE MARK

Controlled Quenching contributes to "flying box car" safety



Battery of B&G Pumps for circulating quench oil.

B&G Quench Tank with B&G Circulating Pump.

Send for Catalog and Simplified Selection Manual

Controlled quenching with B&G equipment is an important step in heat treating landing gear struts for Fairchild "Flying Boxcars". It is one of the processes which assure an end product that will stand up under the high stresses and shocks which occur in landing a heavily loaded plane!

This installation is an outstanding example of excellent heat treating and quenching facilities. Most of the equipment is located in a basement with only the tops of the furnaces and quench tanks exposed above the steel plate floor.

The B&G Quench Tanks have a capacity of 1200 gallons. In the tanks, the oil is not only circulated rapidly and agitated but is changed once a minute by high capacity B&G pumps. Quench oil is drawn from storage tanks in the basement and is held at 135°-140°F. by live steam heat exchangers. With the rapid circulation and agitation of the oil, average loads are brought to quench oil temperature in about 15 seconds.

B&G Oil Quenching Systems are available either as component parts for assembly on the job, or as self-contained packages which combine Coolers, Motors, Pumps, Strainers and all controls into single, integrated units. Engineering service is always available.

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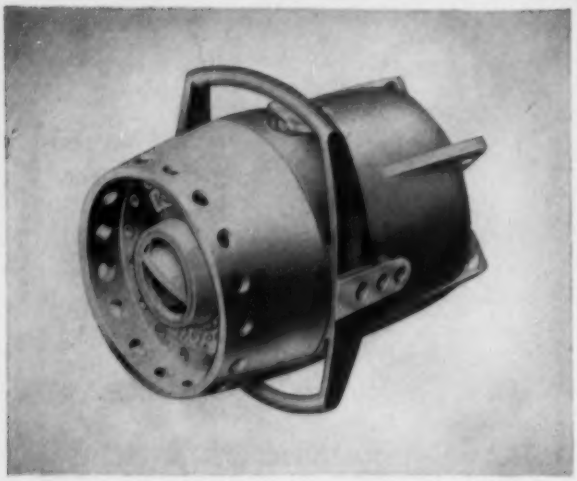
The KEL-RAY Projector

a portable tool for low-cost radiography



Here is a new development employing radioactive cobalt, iridium, or cesium as a source of gamma rays. One of the most practical means yet devised for industrial non-destructive testing, the KEL-RAY Projector lowers costs and simplifies procedures wherever radiographic testing can be applied. Here's why:

PORTABLE—Requiring no external power, the KEL-RAY Projector is available in three portable sizes, the smallest of which can be moved by hand.

SAFE—Ruggedly constructed, equipped with tamper-proof shutter, it is designed and built to keep radiation leakage at a minimum—well below AEC and ICC safety requirements.

ECONOMICAL—Initial and operating costs are low. Requires no maintenance during life of isotope. Set-up time and man-power are minimized.

EASY TO USE—Simple to operate on light or heavy material up to 8 inches thick by anyone properly trained.

For information on how the KEL-RAY Projector can meet your needs, write for Bulletin P 196 P

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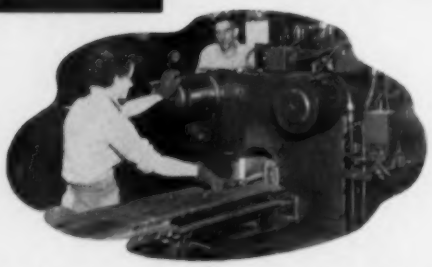

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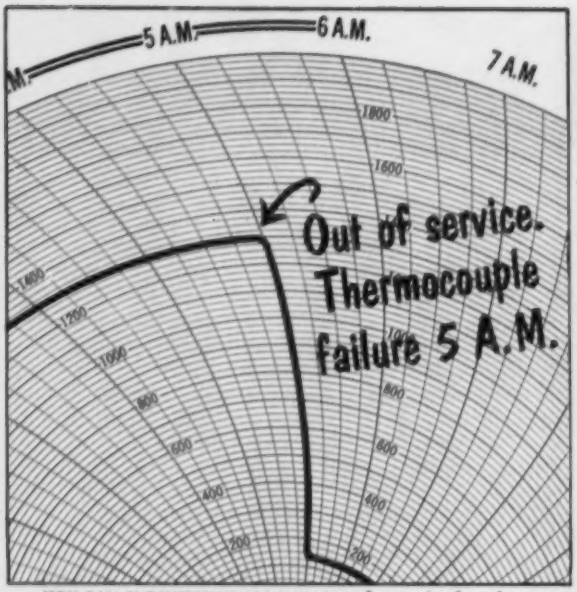

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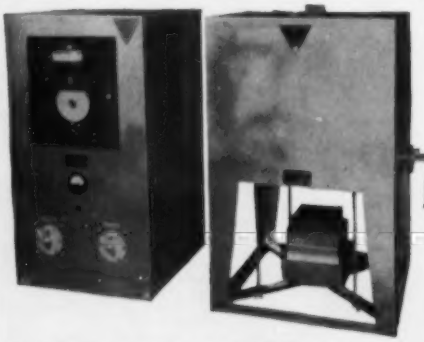

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Model IP-74 maximum temperature 2900° F.

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Standard or Special Furnaces or Kilns for Temperatures from 450° to 5000°F.

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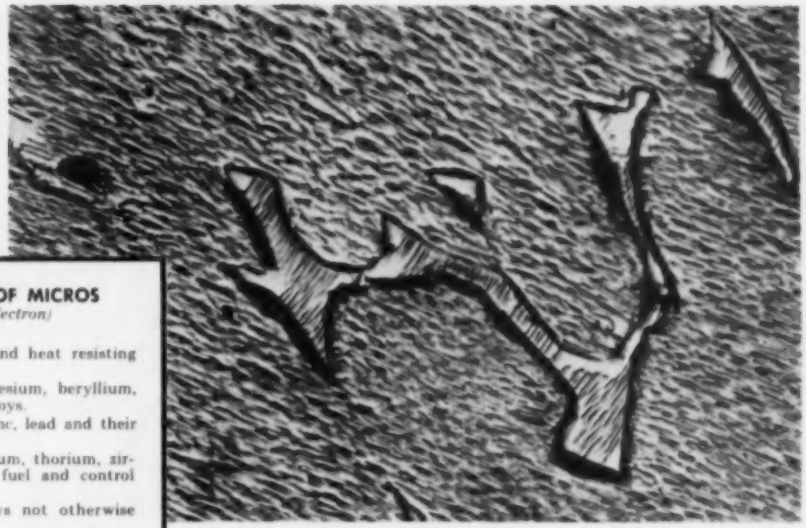
11th Metallographic Exhibit



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(Optical and Electron)

Class 1. Irons and steels.
Class 2. Stainless steels and heat resisting alloys.
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys.
Class 4. Copper, nickel, zinc, lead and their alloys.
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements.
Class 6. Metals and alloys not otherwise classified.
Class 7. Series showing transitions or changes during processing.
Class 8. Welds and other joining methods.
Class 9. Surface coatings and surface phenomena.
Class 10. Results by unconventional techniques (other than electron micrographs)
Class 11. Slags, inclusions, refractories, cermets and aggregates
Class 12. Color prints in any of the above classes (no transparencies accepted)

Entries are invited in the 11th ASM Metallographic Exhibit, to be held at the National Metal Exposition in Cleveland, Oct. 6 through 12, 1956.

RULES FOR ENTRANTS

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable. Photographic prints should be mounted on stiff cardboard; maximum dimensions 14 by 18 in. (35 by 45 cm.) Heavy, solid frames are unacceptable. Entries should carry a label on the *face* of the mount giving:

Classification of entry
Material, etchant, magnification
Any special information as desired

The name, company affiliation and postal address of the exhibitor should be placed on the *back* of the mount.

Entrants living outside the U. S. A. should send their micrographs by first-class letter mail endorsed "Photo for Exhibition—May be opened for customs inspection".

Exhibits must be delivered before Oct. 1, 1956, either by prepaid express, registered parcel post or first-class letter mail, addressed to:

ASM Metallographic Exhibit
7301 Euclid Ave.
Cleveland 3, Ohio

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1957 if so desired.

38TH NATIONAL METAL CONGRESS AND EXPOSITION

CLEVELAND, OHIO **OCTOBER 6 to 12, 1956**

Research or production control analysis problem?

One of these instruments will solve it!

Nearly every business has an analysis problem — either in research, production control or a combination of the two. Now, whether your budget is large or small, whether your requirements are critical or routine, JAco has an instrument tailored to your needs.

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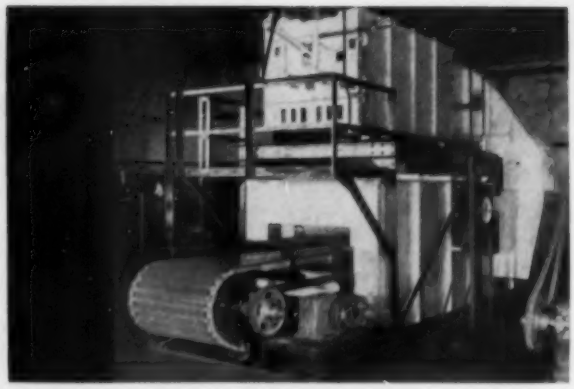

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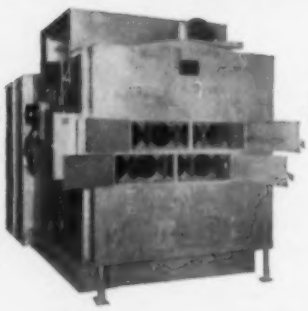

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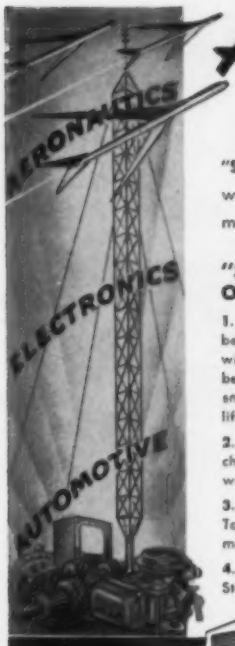

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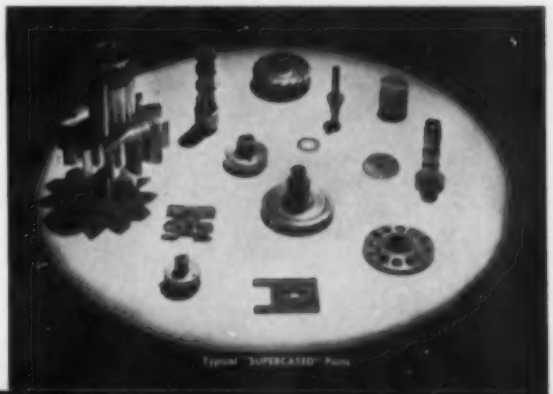

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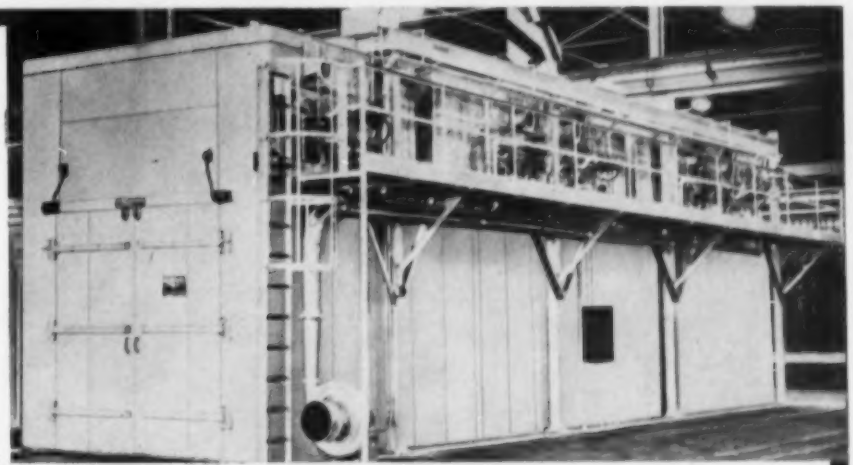

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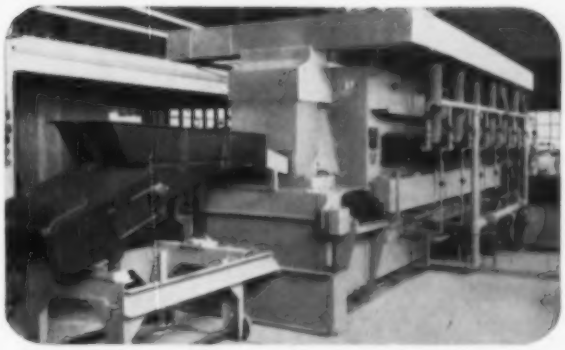
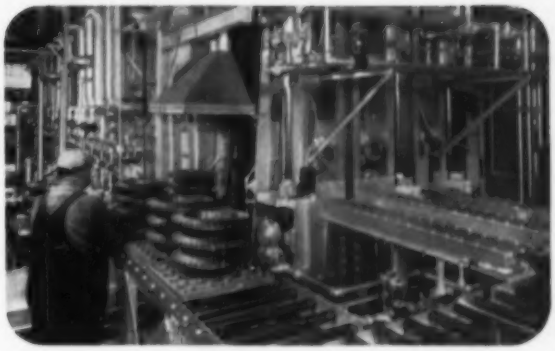


EF gas fired radiant tube combination hardening and dry cyaniding furnace. An automatic feeder distributes parts evenly on conveyor. A partitioned, conveyorized dual quench moves laterally to permit either oil or water quenching.



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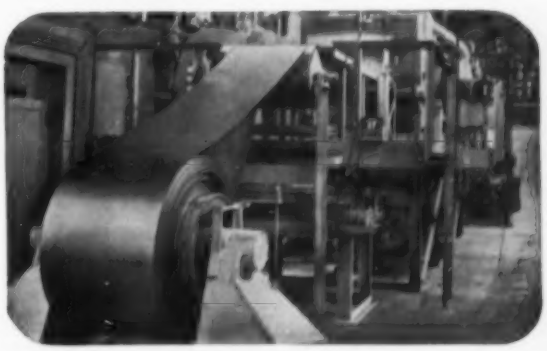

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